M_FC01_Ex_0408_e

E-T-A®
Circuit Protection & Control

Flow Meter FC01-Ex
User handbook

Please follow these installation and adjustment instructions carefully.

Failure to comply with these instructions or misuse of this equipment will void your warranty coverage. The instructions cover software version 2.40.

Equipment installation, connection and adjustment by qualified personnel only.

Failure to comply, or misuse of this equipment, could result in serious damage both to the equipment itself and to the installation. E-T-A is unable to accept responsibility for customer or third party liability, warranty claims or damage caused by incorrect installation or improper handling resulting form non-observance of these instructions.

Monitoring heads are not freely interchangeable with the FC01-Ex. The assembly of mating parts must be maintained.

Electronic control unit and monitoring head are always packed and dispatched in pairs.

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1 Description

The flow meter FC01-Ex is designed to provide stationary monitoring, detection and indication of flow speed, flow volume and medium temperature of liquids, gases and powders with evaluation of the measuring data of the calorimetric monitoring head CST-Ex with separate EC type test certificate.

In addition the FC01-Ex provides power to, and processes output signals from the intrinsically safe type CST-Ex monitoring head. Connections between the intrinsically safe area and the non-intrinsically safe area are via safety barriers. The FC01-Ex control unit must be sited outside the ex area.

2 Ex atmosphere - Definitions and mounting instructions

2.1 Information on explosion protection

The flow monitor FC01-Ex is an "associated electronic apparatus". It has been designed according to the directives the European standards EN 50014 and EN 50020 to type protection:

Ⓔx II (1) GD [EEx ia] IIC.

It carries the Ex type test certification number ZELM 02 ATEX 0117.

The monitoring head CST-Ex is an intrinsically safe apparatus. It has been designed for use as prescribed in explosive atmospheres to directive 94/9/EC and is meant for use in applications of the equipment group II, category 1 (gas zone 0 or dust zone 20).

It has been designed according to the directives of the European standards EN 50014, EN 50020, EN 50281-1-1, EN 50284 and EN 1127-1 type of protection:

Ⓔx II 1/2 GD T130°C IP67 EEx ia IIC T4.

It carries the Ex type test certification number ZELM 02 ATEX 0116 X.

(Available materials and design versions see paras. 2.3 and 2.6.1.1)

2.2 Classification Zones

Classification zones are described for areas where combustible gases, vapours or mist constitute an explosive hazard. When determining the explosion hazard, i.e. when categorising explosive areas, the "directives for avoiding the risks of explosive atmospheres with examples (ExRL)" have to be taken into account. In special cases or in case of doubt the determination is done by the supervising authorities.

2.2.1 Equipment group II, category 1 (Zones 0 and 20)

Equipment of this category is for use in areas where an explosive atmosphere consisting of gas, vapour, mist (zone 1) or of inflammable dust/air mixtures (zone 20) is present continuously or for long periods. Normally this applies only to the inside of containers or apparatus (vaporizers, pipe systems etc.). In these zones only electrical apparatus must be used carrying an EC type test certificate issued by an acknowledged authority and only those which have been explicitly approved for these zones.

2.2.2 Equipment group II, category 2 (Zones 1 and 21)

Equipment of this category is for use in areas where an explosive atmosphere consisting of gas, vapour, mist (zone 1) or a cloud of inflammable dust in air (zone 21) is likely to occur. This may be the case for the surroundings of zones of category 1, the surrounding area of filling or draining systems.

For zone 21 these are also areas where dust deposits occur and during normal operation may build up an explosive concentration of inflammable dust in combination with air.

2.2.3 Equipment group II, category 3 (Zones 2 and 22)

Equipment of this category is for use in areas where an explosive atmosphere consisting of gas, vapour, mist (zone 2) or a cloud of inflammable dust in air (zone 22) is unlikely to occur. If it does, it would be infrequent and for a short time. This may be the case for the surroundings of zones 0 and 1 as well as areas around flange connections or pipe lines in closed areas.

For zone 22 it could also be surroundings of dust-containing apparatus, protective systems and components which might lose dust from leakages and build up dust deposits (e.g. mill rooms, clean air side of filters in outlet air pipes).

(Information according to ExRL, EN50014, EN50281)

2.3 Materials used for calorimetric monitoring heads

The following information contains general recommendations which must be rechecked by the user for the individual application.

2.3.1 Stainless steel 1.4571/AISI 316 Ti

The standard monitoring head material is stainless steel 1.4571, an austenitic, acid resisting stainless steel that is commonly used throughout industry. Manufacturers claim it also withstands oxidizing organic and anorganic acids, and partly even reductive media.

The resistance of this stainless steel should however be verified by the user, particularly when it is used in medium mixtures that may from time to time be exchanged with cleansing agents. Its chemical resistance also depends on temperature, flow rate and concentration of the medium.

Stainless steel owe their resistance to rust mainly to their alloy combination with chromium, the formation of chromic oxide on the steel surface resulting in a passive state. Contamination, deposits on the surface, or foreign rust may however neutralize the passivity. Therefore care should be taken to keep the surfaces clean.

Stainless steel heads must not get in contact with steel parts other than stainless steel or with chemically dissimilar metals, as this would cause electrolytic corrosion.

2.3.2 Nickel-based alloy Hastelloy C4 2.4610

Hastelloy 2.4610 is a material with a chemical resistance generally exceeding that of stainless steel. It is particularly suitable for alkaline media (pH > 7). It should however be examined for suitability for each specific application using resistance tables and pragmatical values.

2.3.3 Titanium G7, 3.7235

Titanium is characterised by non-magnetizability and excellent corrosion resistance, particularly against oxidising media. The resistance is due to the fact that the surface of titanium immediately builds up an oxidation layer in presence of oxidation means protecting the material beneath against corrosion.

The technological characteristics of low-alloy titanium G7 are equal to those of plain titanium of the same strength category. Adding approximately 0.2 % palladium does not influence the mechanical properties, but also adds considerably to the corrosion resistance of plain titanium. So titanium G7 has proved to be extremely suitable for use in hydrochlorid or sulphuric acid solutions with little concentration as well as – with due care – in oxalic acid.

A wide range of applications is possible in aggressive media an zones endangered by sea water.

Please note that physical contact between titanium and magnesium, aluminium, copper or their alloys might lead to increased electrolytic corrosion of these materials.

2.4 Temperature limits

2.4.1 Gases

Maximum media temperature in zone 0 is 75°C. This value also depends on the medium used which might limit the actually allowed temperature.

⚠ According to valid standards for use in equipment group II, category 1 (zone 0) and with regard to avoiding potential ignition sources the temperatures of all surfaces – even with very rare operating troubles – must not exceed 80% of the ignition temperature of an inflammable gas, measured in °C.

Therefore the user has to take care that the temperature limits of his particular medium be expressly stipulated in accordance with the known ignition temperature (see DIN EN 11271, explosive atmospheres – explosion protection. Part 1, para 6.4.2: hot surfaces, category 1).

For applications in category 2 the special temperature limit must only be exceeded in rarely occurring operating troubles.

2.4.2 Dust

The indicated temperature (T +130°C) is the surface temperature of the equipment to be taken into account with a max. ambient temperature of +75°C in zone 20 or 21.

⚠ Therefore the user has to take care that the temperature limits be expressly stipulated by means of the determined ignition temperature (to the method stipulated in EN 50281-2-1) of a cloud of dust or the smouldering temperature of a dust layer of his particular medium (see EN 50281-1-2, electrical apparatus for use in areas with inflammable dust, para 6: temperature limitation).

2.5 Cable length

The monitoring head CST-Ex is connected to the flow monitor FC01-Ex by means of an 8pole, paired connection cable with overall shield.

The shield is grounded on both sides, on the potentially explosive and the non-hazardous side, to prevent inductive interference. To prevent any potentially inflammable currents from flowing over the shield, it is imperative to observe the following:

⚠ **Installation has to ensure to a high degree that there is equipotential bonding between each end of the circuit. In order to ensure that the shield will not become >1 Ohm and induce potential differences, it may be necessary to ground the shield at additional positions.**

If this is technically not possible, the max. cable length has to be restricted to 50 m (see DIN EN 60079-14, Electrical equipment in potentially explosive areas [VDE 0165, part 1], section 12.2.2.3, grounding inductive systems [with example]: special case b).

2.6 Installation - Ex-components

2.6.1 Installation - calorimetric monitoring head

2.6.1.1 Mechanical installation - thread-mounted monitoring head CST-Ex

Application: The monitoring head is designed for use as prescribed in explosive atmospheres to directive 94/9/EG.
The coated sensor tips are immersed into the medium of the equipment group II, category 1 (zone 0 and 20)

Process connectors: G1/2"A (L = 27.5 mm)
G1/2"A (L = 36 mm)
1/2"NPT

Material of area exposed to medium:

stainless steel X6CrNiMoTi17 12 2, 1.4571 to DIN 17440 (V4A) (standard material for water, acids, alkalines, gases)

nickel-based alloy Hastelloy alloy C4 2.4610

Titanium G7 3.7235

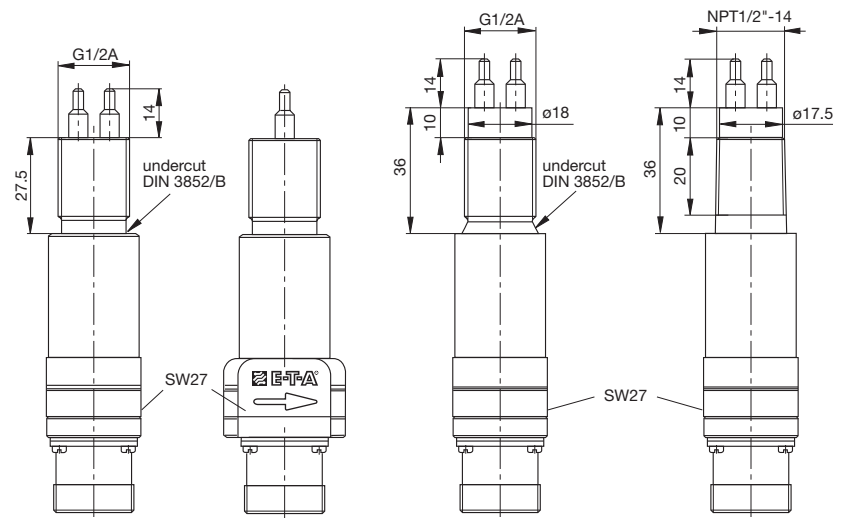


fig. 1

2.6.1.2 Mounting instructions

Check that the monitoring head is suitable for the medium to be monitored. The monitoring head must only be used for media against which the sensor material is sufficiently chemically or corrosion resistant.

When using titanium, particularly according to category 1, installation has to ensure that impact and friction sparks cannot occur.

- ❏ Compare monitoring head with pipe fitting and check, whether fitting or T-piece have the corresponding internal thread and whether the length of the process connection is correct.
- ❏ The two sensors (M) should be screwed into the pipeline far enough to ensure that they are aligned side by side directly across the direction of flow. The sensors are correctly positioned when the wrench flats (S) are aligned parallel with the pipeline.

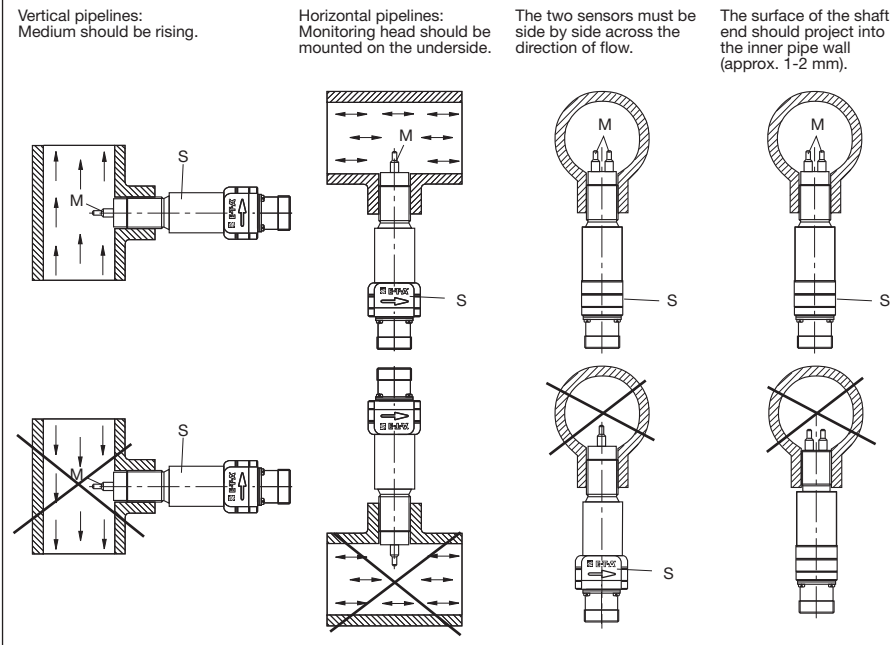

Vertical pipelines:
Medium should be rising.
Horizontal pipelines:
Monitoring head should be mounted on the underside.
The two sensors must be side by side across the direction of flow.
The surface of the shaft end should project into the inner pipe wall (approx. 1-2 mm).
M
S

fig. 2

2.6.1.2.1 Liquid media

- In the case of vertical pipelines the monitoring head should be installed where the flow is rising, if possible.
- For horizontal pipelines the monitoring head should be mounted on the underside of the line (suspended).
- The monitoring head should be installed only in a straight section of piping. There should be a distance of at least 20 pipe diameters before the monitoring head, and 5 pipe diameters after the monitoring head before or after bends and changes in pipe diameter, to avoid any effects of turbulence (fig. 3).
- Flow past the sensor should be from the side marked with a green dot.

2.6.1.2.2 Gases

If gases are to be monitored, the mounting attitude of the monitoring head is unimportant in either vertical or horizontal pipelines. There should be a distance of at least 20 pipe diameters before the monitoring head, and 5 pipe diameters after the monitoring head before or after bends and changes in pipe diameter, to avoid any effects of turbulence (fig. 3).

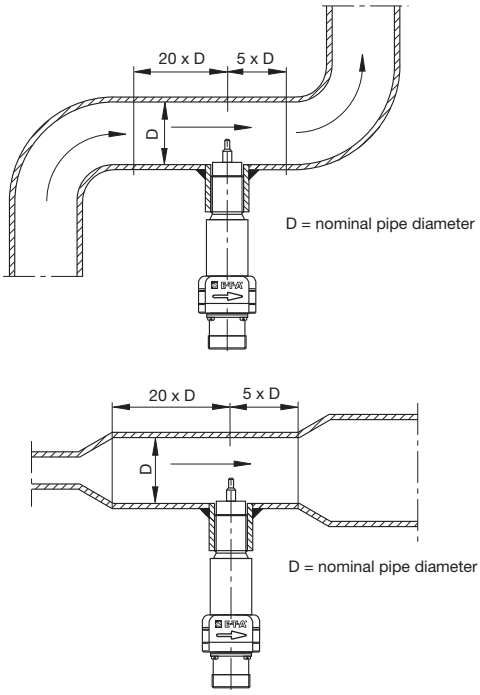


fig. 3

2.6.1.2.3 Depth of threading

The two sensors should be screwed into the pipeline far enough to ensure that the sensors are positioned fully in the flow stream. However, care should also be taken that the sensor is not screwed in too far, thus causing an undue restriction in the pipe bore. It is therefore recommended to connect a union of suitable length to the pipe.

If installed in fittings or T pieces with appropriate internal thread the max. length of the connection piece must be adjusted to the inner pipe wall.

Caution!

⚠ The sensors must be positioned fully in the flow stream.
Observe installation position, direction and required insertion depth.
Ex monitoring heads must be screwed in at least 7 threads.

2.6.1.2.4 Sealing

Use suitable thread sealing, e.g. hemp, teflon band, sealing glue:

- with fitting to DIN 3852, form A (with O-ring) □ length 36 mm
- with fitting to DIN 3852, form B (with sealing face) □ length 27.5 mm

Please pressurize the pipe system and check with regard to leakages.

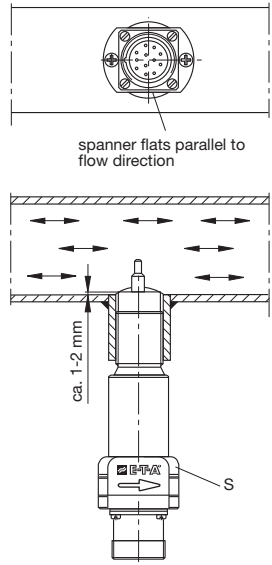


fig. 4

2.6.1.3 Electrical connection

The power supply to monitoring head CST-Ex is an intrinsically safe, ungrounded passive N-terminal output from XSK of the FC01-Ex via Stahl safety barriers, EG-Type test certificate no. PTB 01 ATEX 2053.

Connection is by means of a light-blue LiYCY cable, 4 x 2 x 0.75 mm^2, variable in length.

- Lay signal cable (shielded, blue) to DIN EN 60079-14, para. 12.2.2.3 (see also para. 2.5).
- Install equipotential bonding along the complete cable run of the intrinsically safe circuit

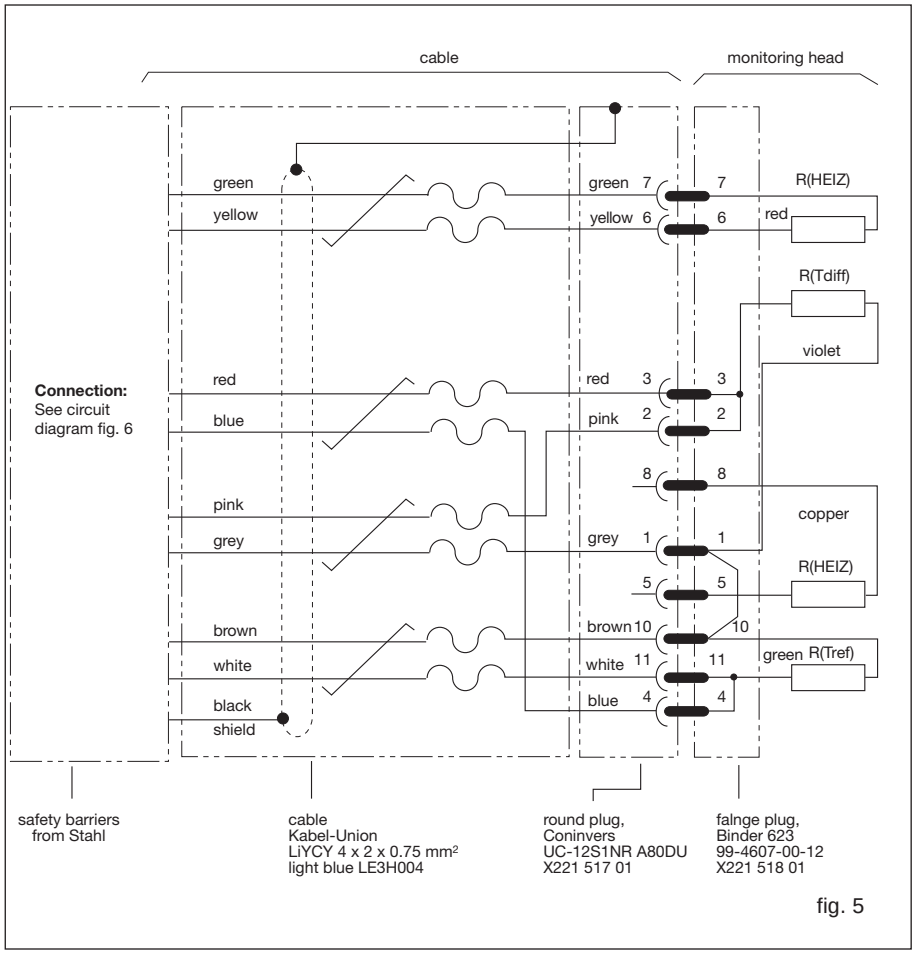
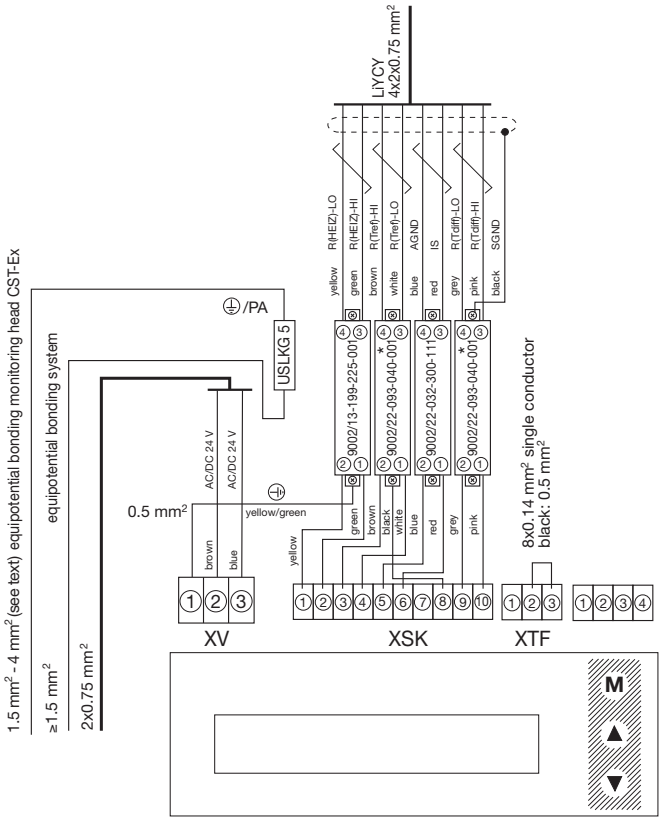


fig. 5

from the monitoring head to the grounding system near the flow meter.

Min. cross section for protected installation is 1.5 mm², for unprotected installation 4 mm².

- Hand tighten connector of the signal cable to the monitoring head.



* identical with 9002/77-093-040-001

fig. 6

2.6.2 Installation of electronic control unit FC01-Ex

2.6.2.1 Mechanical installation

- The enclosure is installed by 4 retaining screws.
- The blue strips over the screws should be removed to allow the front cover to be eased out of the enclosure.
- The surface mounted enclosure meets protection degree IP54.

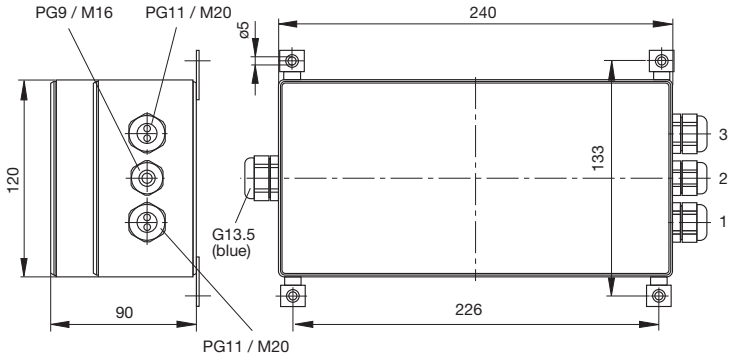


fig. 7

2.6.2.2 Electrical connection

- Take the FC01-Ex equipotential bonding cables (≥1,5 mm^2), from the monitoring head through the cable gland 1 (fig. 7) and to the centre grounding system (fig. 6) and connect to terminal USLKG5.
- Take the cable of the monitoring head through the cable gland and connect to the barriers according to the connection scheme FC01-Ex (fig. 6).
- Take supply feed through cable gland 2 and further required connection cables through cable gland 3 (fig. 7) and connect to terminals XV (see connection scheme fig. 6).

XV - Power supply

Connection by 3 pole connector; A_{max} = 1.5 mm^2; 3 x 0.75 mm^2 cable recommended

Pin No.	Signal name	Function
1	SGND	general reference ground/shield ground
2	$+U_V$	positive pole of supply voltage
3	$-U_V$	negative pole of supply voltage

XTF - Keyboard release

Connection by 3 pole connector, factory-wired

XAO - Analogue outputs

Connection by 8 pole connector; A_{max} = 1.5 mm^2; LiYCY 2 x 0,25 mm^2 cable recommended, stripped length 6.5 mm

Pin selection for analogue outputs V1, V2, C1

Pin No.	Signal name	Function
1	NC	none
2	ANAO1	analogue output 1 - flow
3	ANA1GND	reference potential for analogue output 1
4	SGNDA1	shield for analogue output 1 (ungrounded)
5	SGNDA2	shield for analogue output 2 (ungrounded)

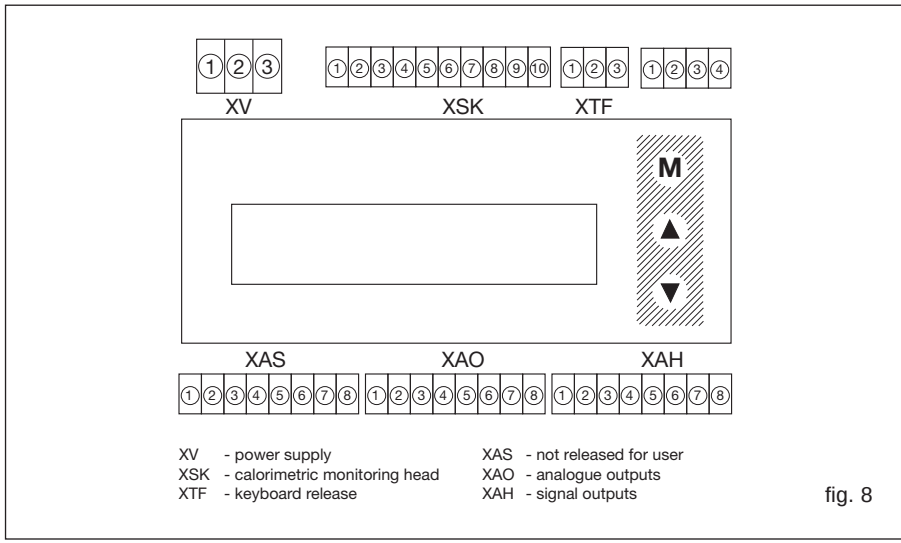


fig. 8

6	ANAO2	analogue output 2 - temperature
7	ANA2GND	reference potential for analogue output 2
8	NC	none

XAH - Limit value signal outputs - relay outputs - change over contacts

Connection by 8 pole connector; A_{max} = 1.5 mm^2, LiYCY 3 x 0.38 mm^2 cable recommended, stripped length 6.5 mm

Pin No.	Signal name	Function
1	SGNDL1	shield ground 1
2	LIM1	non-inverted signal output 1 (N/O)
3	LIM1COM	common change over input 1
4	/LIM1	inverted signal output 1 (N/C)
5	SGNDL2	shield ground 2
6	LIM2	non-inverted signal output 2 (N/O)
7	LIM2COM	common change over input 2
8	/LIM2	inverted signal output 2 (N/C)

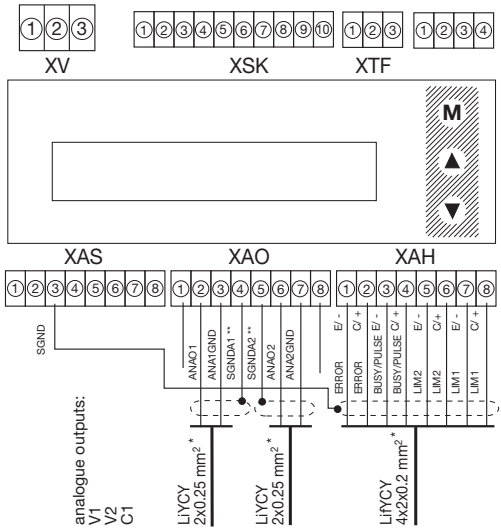
XAH - Signal outputs - transistor outputs (NPN, freely connectable)

Connection by 8 pole connector; A_{max} = 1.5 mm^2, LifYCY 4 x 2 x 0,2 mm^2 cable recommended, stripped length 6.5 mm

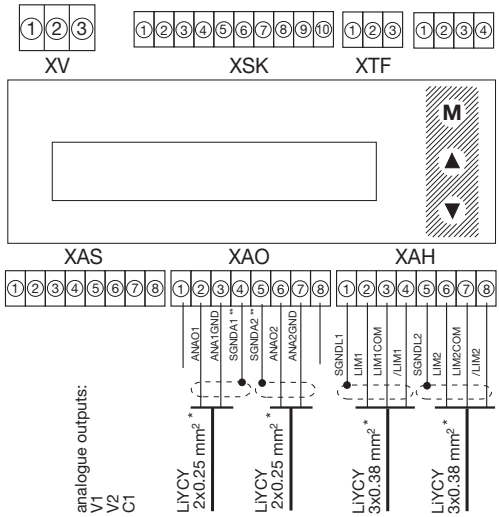
Pin No.	Signal name	Function
1	/ERROR E	summarized error indication - emitter terminal
2	/ERROR C	summarized error indication - collector terminal
3	/BUSY/PULSE E	availability signal or frequency output - emitter terminal
4	/BUSY/PULSE C	availability signal or frequency output - collector terminal
5	LIM2 E	limit value 2 - emitter terminal
6	LIM2 C	limit value 2 - collector terminal
7	LIM1 E	limit value 1 - emitter terminal
8	LIM1 C	limit value 1 - collector terminal

2.6.2.2.1 Circuit diagram FC01-Ex

Version: 24 V, open collector outputs



Version: 24 V, relay outputs



E/ - emitter terminal
C/+ collector terminal
* recommended
** SGNDA1, SGNDA2 } ungrounded

Apply shield on one side only.

fig. 9

2.6.2.2.2 Electrical connection - frequency output (version FC01-Ex-U1T4)

The quantity-dependent pulse to operate a counter or higher-order control is available at connector **XAH** /BUSY E/- and /BUSY C/+ (pins 3 and 4) (see fig. 9 - Circuit diagram FC01-Ex - open collector output).

Signal ground shall be connected to pin 3 (BUSY E/-) and the driving load to pin 4 (BUSY C/+).

Select cable size ≤ 1.5 mm^2 to make the connections.

The shield can be connected to connector **XAS**, pin 3.

Electronic signal processing

If the frequency output of the FC01-Ex is connected to an electronic counter, computer or PLC, the load current should not exceed 10 mA so as to ensure low level is 0.8 V. The max. admissible voltage level of 48 V is irrelevant in this connection.

Typical circuit (example 1)

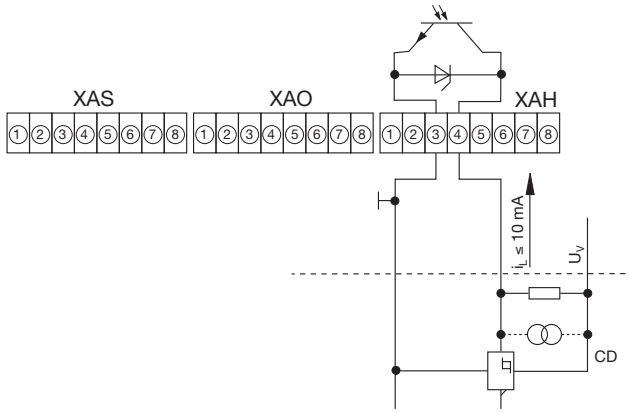


fig. 10

The FC01-Ex driver output comprises an integral safety circuit which when isolating the counter operating coil will limit overvoltages caused by inductance and convert the energy stored.

The counter should be able of processing a counting frequency of ≥ 10 Hz.

Pulse duration is not dependent on frequency and maintained at 50 ms (±0.1%).

It should therefore be ensured that the counter can be increased by one during the time available.

If a separate relief network is preferred to the integral network, care should be taken when processing the max. frequency of 10 Hz to ensure the energy stored in the operating coil has dissipated by the time the counter output is reset. The time to do this should be below 40 ms, making due consideration to switching times and pulse variations.

Typical circuit (example 2)

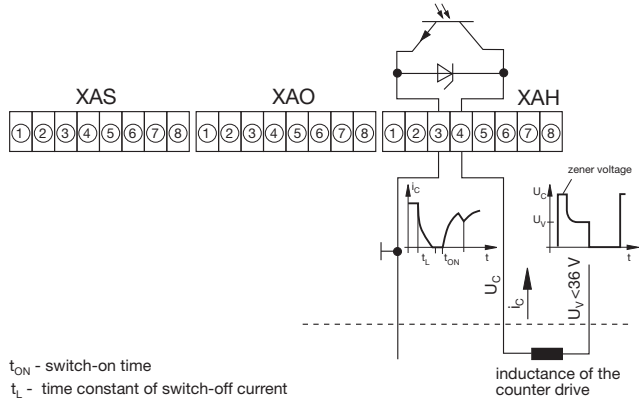


fig. 11

Note:

- ❑ As there will be a reset pulse available at the output in the moment the supply voltage of the FC01-Ex is applied, make sure that the counter is switched on delayed or set to zero after it has been switched on.

2.7 Maintenance

2.7.1 Monitoring head CST-Ex

The monitoring head is virtually maintenance-free with media which do not collect on the sensors.
In case of deposits on the sensors these have to be cleaned at the necessary intervals.

⚠ Avoid damaging the sensors during cleaning as the explosion protection depends on the intactness of the sensor coating.

2.7.2 Flow Meter FC01-Ex

The Flow Meter FC01-Ex is maintenance free. With regard to software the device is fitted with a wide range of checking and testing functions described in chapter 7.

3 Normal atmosphere - Definitions and mounting instructions

3.1 Measuring procedure

The calorimetric measuring procedure is based on the physics of heat dissipation, i.e. a body with a temperature higher than its surroundings supplies a medium flowing past that body with energy in the form of heat. The amount of energy supplied is a function of temperature difference $\Delta\vartheta$ and mass flow.

Flow Meter FC01-Ex operates on the CTD (Constant Temperature Differential) method:

The temperature difference □□ between the two sensors is kept constant and the mass flow is determined by measuring the calorific power.

Fig. 12 is a schematic diagram of a CTD method based sensor. Two temperature-sensitive resistors (sensor elements RS and RM) are immersed in the medium. Sensor element RM assumes the temperature ϑ_M of the medium whilst heater resistor RH heats element RS to temperature ϑ_S. As a function of the medium, the temperature differential □□ = ϑ_S - ϑ_M is preselected as a reference variable by the CTD control with ∏ characteristics and is kept constant. The required calorific power is a function of mass flow so that the control variable **y** of the control can be used for evaluation.

Major benefits of this method are:

- Fast response, particularly to sudden flow standstill.
- Medium temperature measurement, providing optimum temperature compensation.
- Increased safety because the sensor cannot be overheated during the standstill.

The flow rate is determined by mass flow.

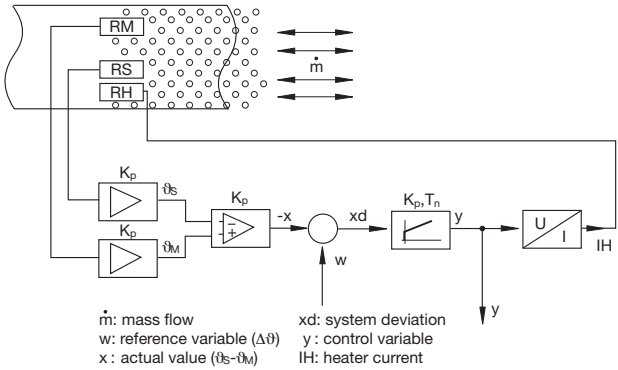
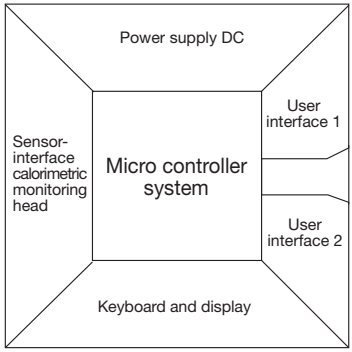


fig. 12

3.2 System description

The system comprises the following hardware functional modules:

Input voltage	DC supply voltage (terminal XV)
User interfaces:	
analogue outputs	1 and 2 (terminal XAO)
signal outputs	2-way or 4-way signal outputs (terminal XAH)
Sensor interface:	calorimetric monitoring head (via safety barriers)
Keyboard and display:	touch switches
	liquid crystal display
Micro controller system:	signal processing and monitoring



Input voltage:	DC 19 … 32 V	
Keyboard/display:	touch switches LC display 2 x 16 digits	
User interface 1:	relay outputs: transistor outputs:	2 limit values 2 limit values + 1 error indication + 1 busy signal or frequency output (software selected)
User interface 2:	analogue outputs current or voltage	
Controller system:	signal processing I/O - controlling monitoring parameter memory	
Sensor interface:	calorimetric monitoring head	

fig. 13

The power supply is physically isolated between power supply input and system power supply output. This also applies to the analogue outputs which are physically isolated from each other as well as from the other electronics and the signal outputs. The signal output channels are also separate and electrically isolated from the central electronic unit.

There is no electrical isolation between monitoring head and central electronic unit.The dielectric strength of the monitoring heads is specified in our CPI catalogue.

Connection of the monitoring heads is by means of precut cable links.

Cables and user interface connections are shown in para. 2.6.2.2 and circuit diagram 2.6.2.2.1.

System configuration and parameter setting are by means of the keyboard if default values need to be changed (paras. 5.1.1 and 5.1.2)

This mainly applies signal outputs (switch point setting) and analogue outputs (zero point setting and scaling).

3.2.1 User interfaces

Signal outputs: (optional)

1. R2 - Relay outputs (2 limit values)
Two-channel physical isolation, relay change over contact

The channels may be assigned, either individually or in pairs, to the physical quantities of temperature or flow. The switch on and off values can be set as desired (yet within the measuring range) for each contact. Please see para 8.5.1 for electrical connection.

2. T4 - Transistor outputs (2 setpoints + 2 status outputs or 1 status output + 1 frequency output)

Four-channel physical isolation, transistor output - collector/emitter freely connectable

channel 1: common error signal

channel 2: busy signal or frequency output

channel 3 and 4: Both channels may be assigned individually or in pairs to the physical quantities of temperature or flow. The switch on or off values of each transistor output can be set as desired.

Please see para 8.5.2 for electrical connection.

Analogue outputs:

Two-channel physical isolation, current or voltage output

Please see the ordering number to find out whether it is a current or voltage output.

Output quantities: 0/1 - 5 V FS (V1)
0/2 - 10 V FS (V2)
0/4 - 20 mA FS (C1)

These FS (full scale) output quantities apply to both channels as standard.

20% zero elevation and FS value can be programmed. (See para. 5.1.1.12)

Shield connections are ungrounded.

The shields of the signal cables should be applied on one side only.

Power supply:

DC supply with physical isolation of the primary and secondary side.

Power supply is by means of an isolating transformer. One of the secondary voltages is regulated as actual value. The control variable is fed, physically isolated, to the pulse duration modulator.

Noise emission on the connection cable is limited by circuit design and filter.

A PTC is used as overcurrent protection. After remedy of the failure it resets automatically.

Please see para. 8.2.1 for technical characteristics.

3.3 Customer calibration

The FC01-Ex functions are mere software functions which do not affect the FC01 hardware.

Generally, a flow characteristic value is assigned to each control variable of the temperature differential controller (with the variable equalling the heating power) by adjustments as described within the menu.

Up to 20 trim points can be assigned to the flow characteristic curve, i.e. the calibration range. This distribution of the trim points being determined by the user within certain ranges of the flow characteristic curve, resolution and accuracy are determined by that distribution. By extrapolation the measuring range is expanded beyond the max. flow value by 10% of the upper trim point.

The lower trim point can be optionally set between the zero point of the characteristic curve and the last but one trim point. If the setting is selected above the zero point, the characteristic curve will be extrapolated by 10% of the measuring range below the lower trim point or to the zero point. The limit values and the analogue outputs can be set, or scaled, between these limits.

3.3.1 Options and benefits of customer calibration

Custom designed calibration allows for anomalies within medium or system variations, and the high repeatability of the measuring procedure makes it possible to measure and indicate flow conditions with a high degree of accuracy.

This requires that a higher-order measuring unit, or reference quantity, be available, from which the FC01-Ex is then calibrated and set. The characteristic curve may be determined for each individual requirement or it can be transferred from one system to another with resultant lower accuracy.

Note:

- A suitable reference instrument is required in each case.
- **Adjustment in the field**: Consideration must be made as to the **medium and flow conditions** available;
  reference instrument required.
- **E-T-A factory calibration:** **Calibration in measuring pipes** (integral system)
  Calibration of: water, various oils, air

3.3.2 Special flow and installation conditions

The measuring system generally implies defined flow conditions, to establish the flow characteristics of our standard characteristic curves. This requires that certain mechanical dimensions within the pipeline, such as distances before and after the monitoring head, before or after any bends and changes in pipe diameter, mounting attitude of the monitoring head (e.g. immersion depth), and any restrictions caused by turbulent or asymmetric flow be considered.

It is often difficult in compact systems to satisfy these requirements, or to judge the consequences when they are not fully met (e.g. missing flow straighteners). The FC01-Ex allows the user to partially or completely eliminate any serious consequences by means of its calibration features.

3.3.3 How to achieve higher accuracy

As a result of the relevant physical properties and the characteristics of the monitoring head, any variations of control variables will be very small and nearly linear in the event of high flow velocities, whereas with low flow velocities there will be a high signal variation with resultant high non-linearity. By setting the interpolation trim points close enough, the error can be kept below 1% over wide distances of the measuring range.

Another influence is that of the temperature difference selected.- See section 4.2.1)

3.3.4 How to achieve the full scale range

As the trim points can be optionally distributed in a fixed sequence on the characteristic curve, together with the appropriate selection of the sensor temperature, that part of the curve which is most important for the application can be given a particularly high resolution.

Note:

- ❑ The accuracy is a function of how close the trim points are distributed. (See section 9 - Examples).

3.3.5 Pin-point adjustment (selective accuracy)

If one or several flow values (e.g. flow limits, cooling power limit etc.) are particularly important for the system, they can be assigned to one trim point each to achieve a high degree of dependability and accuracy in meeting the control criteria.

3.3.6. Reproduction of precise measuring instruments

The customer calibrated (-Ex) version of the FC01 allows the user to reproduce expensive measuring instrument data in his characteristic curve. Thus expensive measuring instruments need only be purchased once, if at all.

3.3.7 Use of standard monitoring heads

(separate heads for gases and liquids)

Monitoring heads are not freely interchangeable with the FC01-Ex, i.e. in the event of a failure the complete pair monitoring head/electronic control unit must be replaced.

4 Technical implementation of customer calibration

The FC01-Ex can be used to establish a new pipe-depending curve, or to enter or store it as a theoretical curve.

4.1 Calculation

Interpolation between the trim points is linear. This applies both to the velocity values and the control variables to be assigned by the user, i.e. the velocity-dependent heating power required to maintain a constant temperature differential between the medium and the heated probe in the case of a calorimetric sensor.

Beyond the maximum and minimum trim point, extrapolation is made by 10% each of the applicable upper measuring range value. As the sensor is not direction-sensitive, the minimum flow value displayed will be zero.

Maximum number of trim points: 20

Minimum number of trim points: 2

The maximum trim point is assigned to the maximum velocity; the assignable velocity decreases with a descending trim point index.

Definition:

V_n (velocity assigned to setpoint n)

n = 2 … 20 (trim point index)

Condition for the trim points:

$V_n < V_{(n+1)}$ ..... ≥ 0

4.2 Calibration

4.2.1 Selection of CTD value (temperature differential)

It is possible to select an optional temperature differential setpoint, within a temperature limit of 3.0 °C and 15 °C, providing that 90% I_{max} of this current heating power is not exceeded, to indicate the temperature differential at max. flow velocity (90 % I_{max} ≙ Y = 36864 Digits).

Error (error 30) will be indicated if this limit is not observed during calibration. The user will then have to select a lower temperature differential.

As different media have different heat transfer capacities (specific heat) and densities, CTD value selection also depends on the medium to be measured.

Please see the following table and assignment list for guidance.

Class 1: gases

Class 2: granules, dust and other mixtures containing solids

Class 3: water and similar media, oils and other homogeneous liquids, and liquid mixtures

Note:

- ❑ The measuring procedure necessitates a homogeneous distribution of substances/mixture. Varying mixtures can only be detected by higher-order systems.

  The particle size of class 2 media must not exceed 2 mm.

Medium: Med

Flow velocity: V

Temperature differential: □□

Mass: m

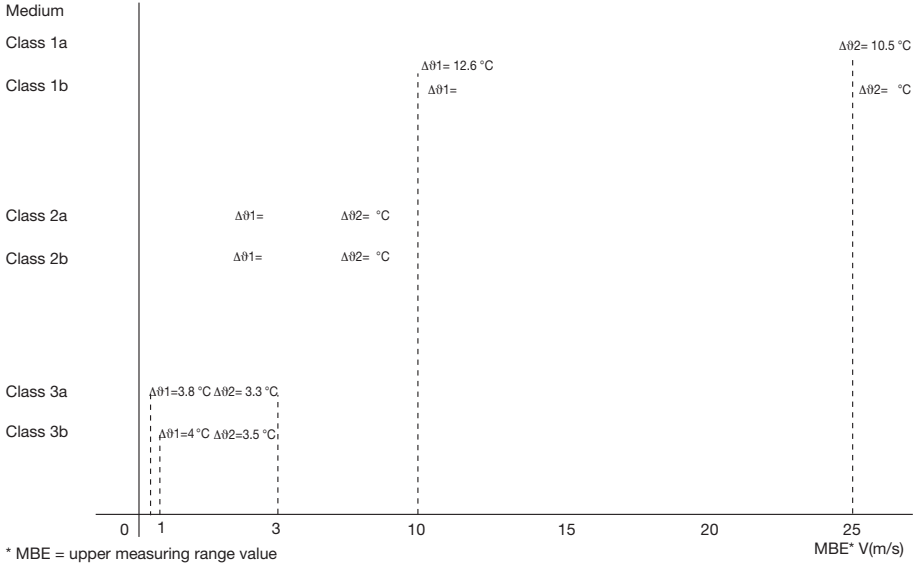
Specific heat: c

Density: □

Assignment table - Medium / Flow velocity / Temperature differential

Class/Medium	Chemical symbol	V [m/s]	□□ [°C]	□ [g/dm³] 0 °C, 1 bar/14.7 PSI	c [cal/g °C] 20 °C, 1 bar/14.7 PSI
Class 1					
a: air		25	10.5	1.293	0.24
oxygen	O2	25	10.5	1.429	0.219
nitrogen	N2	25	10.5	1.25	0.249
nitro oxide	NO	25	10.5	1.34	0.237
carbon monoxide	CO	25	10.5	1.25	0.249
deuterium		25	10.5	0.1798	1.731
fluorine	F2	25	10.5	1.696	0.197
hydrogen	H2	25	10.5	0.08991	3.42
hydrogen bromide	HBr	25	10.5	3.646	0.086
hydrogen chloride	HCl	25	10.5	1.639	0.191
hydrogen fluoride	HF	25	10.5	0.8926	0.348
hydrogen iodide	HI	25	10.5	5.799	0.054
Class 2: We currently don't have much experience with the use of such media, but generally the FC01-Ex can certainly be used.					
Class 3				4 °C	20 °C
a: tap water		3	3.3	1	1
high-purity water		3	3.3	1	1
seawater		3	3.3	1.03	1
b: water glycol (1:1 … 2.5:1)		3	3.5		

Assignment graph - Medium / Flow velocity / Temperature differential



* MBE = upper measuring range value

4.2.2 Trim point selection - number and position

Between 2 and 20 trim points can be set.

They are addressed in a “downward” sequence to ensure the user can recognize the trim points still available by the trim point index indicated.

A reasonable distribution on the characteristic curve depends on the desired accuracy, the required measuring range or continuity criteria such as differentiating criteria. These issues are addressed in section 9.

Generally, there are fewer trim points needed in the upper characteristic curve range than in the lower range, the reason for this being the flattening characteristic curve (see section 9).

Depending on the medium and the measuring range, it is possible to use different procedures in selecting the trim points.

A linear preselection of the trim points has been provided for in the FC01-Ex. With the appropriate number of trim points set, this procedure achieves good results over the entire velocity range (5 m/s with water, 25 m/s with air).

A trim point distribution which significantly reduces the measuring error when compared to a linear distribution, can be determined by the following formula (see 9.2 - Example 2).

$$MB = ME - MA$$

$$AB = MA + (MB \times (1 - e^{-(((SP-1) \times g)/SG)}))$$

$$g = 2.5 \times (SP - 1)/SG$$

AB -	trim value [m/s]	SP -	trim point No. SP = 1 … SG
MA -	lower measuring range value [m/s]	SG -	overall number of trim points
ME -	upper measuring range value [m/s]	g -	distribution coefficient
MB -	measuring range [m/s]		

4.2.3 MAX-MIN Calibration procedure

The MAX/MIN calibration procedure has been selected because the critical parameter (max. heating power) is determined in the computer background after the first calibration step (max. flow velocity).

If too high a temperature differential has been selected for the heater control to indicate, this is displayed as “error 30”. It is then immediately possible to reduce the temperature differential to a value the controller is able to indicate (see para. 4.2.1, Selection of CTD value).

It is thus verified and ensured when starting the calibration that the flow characteristics can be displayed, eliminating that a curve must be dropped because its last trim point(s) cannot be indicated.

4.2.4 Zero point, directional discrimination and upper characteristic curve value

The zero point of the characteristic curve and the zero point of flow need not be identical. If the zero point of the characteristic curve - lowest trim point - is above the zero point of flow, the characteristic curve is linearly extrapolated down by 10% MBE (= upper measuring range value) so as to extend the calibration range of the FC01-Ex.

However, the extrapolation is only effected to the theoretical zero point as the measuring system does not operate in a direction-selective way.

If the zero point of flow and the zero point of the characteristic curve are identical, the control variable should be increased by 300 to 400 digits to suppress the convection-dependent variation of the zero point.

In the same way that the calibration range can be extrapolated downward by 10% MBE, so can the upper calibration range be extrapolated by 10% MBE above the upper trim point. Error indication because of minor over limits of the upper calibration range values can thus be eliminated. The extended characteristic range will then be fully available when determining the analogue output, the limit values and the bar graph.

4.2.5 New curve / Old curve

4.2.5.1 New curve

The following automatic processes have been provided for to facilitate and accelerate the calibration or manual entry of a new curve.

1. Preloading of zero point control variables

As a result of parasitic heat transfer points a big part (approx. 50%) of the heating power is not transported through the medium but rather through the housing and the electrical cables. The heating power control variable with zero flow has already a value above 25,000 digits.* Preloading the setting value for the lower trim point with that value obviates the need for passing through a wide setting range (timesaving benefit).

* Provided the temperature differential has been selected appropriately (see para. 4.2.1 for recommended values).

2. Linear preloading of interim values for velocity and control variable

The calibration range left between the last addressed and established trim point and the zero point is linearly divided among the remaining trim points. This applies both to velocity quantities and control variables. It generally ensures that only a small calibration range needs to be passed (provided that 1. has been satisfied).

In this operating mode - new curve - an already existing curve (old curve) would be deleted. If the new curve is completely entered by hand, it is necessary to enter the TK reference temperature (see 5.1.1.4.7) when quitting the menu.

The TK reference temperature is the medium temperature at which the curve was established under normal operating temperature conditions.

If the calibration of a new curve is made selecting temperature differences which are essentially smaller than the values recommended, the zero point on the characteristic curve will be displaced towards smaller control variables. It may happen then that the first trim value is below or on the preloaded zero point value, in which case the software will provide that the initial values for further control variables are below the established preceding value.

4.2.5.2 Old curve

In this operating mode, each trim point can be corrected without jeopardizing other existing data.

Changes are limited by the general calibration conditions. This means that the values assigned to a trim point can never be higher than the values assigned to the trim point above, or lower than the quantities assigned to the trim point below.

Caution!

⚠ Changes/expansions of old curves must only be made whilst maintaining the temperature differential.

4.2.6 Transfer of C- and T values - Re-establishment of T value

As the monitoring heads are factory preset for air or water, their C and T values apply only to those media.

When the heads are used in gases or gas mixtures similar to air (see table page 26), these values can be transferred. The same applies to heads monitoring water.

In that case the temperature difference (water 3.3 °C, air 10.5 °C) must be set in the CUSTOMER TRIM menu to calibrate a characteristic curve.

The following medium characteristic quantities should however harmonize as far as possible:

a. density ρ

b. specific heat c

When other media are used, the C value may be transferred, but the T value should be separately established and set for recording the new curve at T = 50.

4.2.6.1 Establishing the T value - general

The T value should be established at a velocity in the upper third of the calibration range.

When recording the characteristic curve, the temperature and the control variable at a trim point located in the upper third of the characteristic curve (70 - 80% V_{max}) should be noted.

T1 = . . . , . °C	medium temperature when recording the new curve
Y_{T1} = ... digits	control variable
V_{T1} = . . , . . m/s	flow velocity at temperature T1

Control variable Y_{T2} is then established at the same flow velocity ($V_{T2} = V_{T1}$), ideally at the highest medium operating temperature.

Conditions: $V_{T1} = V_{T2}$

T2 > T1

The following quantities are recorded:

T2 = . . . , . °C	upper setting temperature of the medium
Y_{T2} = ... digits	control variable with T2

The following quantities are recorded:

$$T = 50 + (Y_{T2} - Y_{T1}) / (T2 - T1)$$

The resultant T value is filed in the configuration menu under SENSOR SELECT - TYPE CALORIM-CODE T… .

4.2.6.2 Establishing the new T value

At first, a new curve has to be recorded by setting the **T value** in the SENSOR SELECT menu at **T = 50**.

With heads monitoring water or air (see introduction to this section) it is possible to use the **C value** if similar media are to be monitored. It is necessary to set **C1000** as basic value if the characteristic quantities of a medium cannot be assigned to a medium group.

After setting the **C** and **T values**, the number of trim points and the temperature difference shall be defined in the CUSTOMER TRIM menu.

Record the new curve as described, observing constant temperature conditions (T1, Y_{T1}, V_{T1} as described).

After establishing and storing the new curve, the medium shall be heated to setting temperature (T2).

Then return to the CUSTOMER TRIM menu and select option **old curve**.

Address the trim point the control variable of which you wish to establish at temperature T2 and the same velocity as when recording the new curve.

Compare the following values displayed:

TRIM POINT …

V = . . , . . m/s

Y = ... (Y_{T1}) with the values noted.

These values shall still be assigned to the old curve which was recorded at temperature T1. Then set velocity **V** at the higher temperature T2.

Activate the automatic control variable determination in menu **TRIM ACTIVE**.

When the FC01-Ex has determined the new Y value, it is displayed and recorded (Y_{T2}) as it is needed for subsequently calculating the T value.

Temperature T2 (please note down) which will also be included in the calculations is displayed before the calibration menu is quitted.

Then quit the menu without storing the data (▲ UP or ▼ DOWN) to prevent overwriting the old curve.

The new **T value** is calculated by inserting the values determined for Y_{T1}, T1, Y_{T2}, T2 into the formula.

Set the new T value in the configuration menu under SENSOR SELECT.

4.2.7 Expanding the characteristic curve

The characteristic may easily be extended upward when the temperature difference has been selected so as to provide sufficient reserve heating power (normally ensured by the curve getting flat at higher velocities).

Note

- ❑ Consider some reserve for the heating power (3.2.1, Selecting the temperature differential) when establishing a curve that is intended subsequently to be extended.

The extension can be made either by manually entering quantities Y and V to be assigned, or in menu point TRIM ACTIVE giving a flow velocity

.**Note:**

- ❑ It is not possible to include new trim points in an existing characteristic curve!

5 Operation

5.1 Operating system

Clear menu-driven control, via keyboard and display, enables easy definition of parameters and configuration. This provides high system flexibility, making the FC01-Ex the optimum solution for a wide variety of measuring, monitoring and display tasks.

All functions are distributed on the three following menu levels:

HAUPTEBENE (-MENÜ)

KONFIGURATIONSEBENE (-MENÜ)

PARAMETRIERUNGSEBENE (-MENÜ)

See Appendix 5 listing all functions available.

Touch switches

Setting and configuration is by means of three front touch switches: **M** MODE, ▲ UP and ▼ DOWN.

Caution!

⚠ The FC01-Ex can only be set or operated when connector XTF (keyboard release) is removed

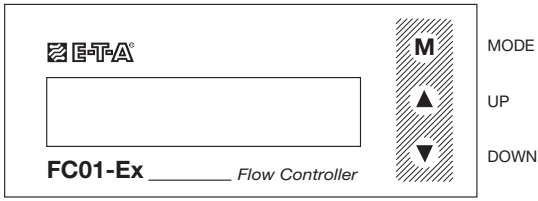


fig. 14

Menu paging

The next menu option is selected by pressing **M** MODE (forward paging).

Pressing **M** MODE after the last menu option will cause skipping to the first option of the menu.

Calling a menu option

Simultaneously pressing ▲ UP and ▼ DOWN calls the selected menu option, or causes skipping to the selected submenu.

Entry of numerals

Some menu options require numerical values to be entered. After selecting the appropriate menu option, the value indicated can be changed by pressing ▲ UP or ▼ DOWN.

Each time ▲ UP or ▼ DOWN are pressed, the value indicated will be increased and reduced respectively, by one numeral skip. The longer ▲ UP or ▼ DOWN are pressed, the faster the increase or reduction.

Transfer of entries

Pressing **M** MODE transfers the set value or the selected menu option to a volatile memory. A permanent transfer of settings and values is only effected when quitting the menu, after a plausibility check of all entries.

Afterwards the data will be available even after repeated on/off operation of the FC01-Ex.

Deleting data

Selected data such as MIN and MAX values can be deleted or reset by simultaneously pressing ▲ UP and ▼ DOWN.

5.1.1 Configuration

The CONFIGURATION menu serves to adjust the FC01-Ex to its application within the entire system.

During system configuration, measuring operations are not possible (see Appendix 1).

Configuration possibilities are:

5.1.1.1 Selection of monitoring head (menu option: **SENSOR SELECT**)

The menu covers only one calorimetric monitoring head type so that it is not necessary to enter further details.

5.1.1.2 Monitoring head data (menu option: **SENSOR CODE**)

To operate the FC01-Ex it is necessary to set sensor-specific characteristics.

These characteristics are specified by the sensor code which together with the monitoring head type number is marked on the monitoring head housing.

Setting is menu driven in two steps:

1. Setting of the C characteristics C range: 700 … 1300
2. Setting of the T characteristics T range: 01 … 99

5.1.1.3 Medium selection (menu option: **MEDIUM SELECT**)

This menu option is used to select the medium in which the Flow Meter is used.

The following media are called:

* GAS
* FLUID

5.1.1.4 Custom designed calibration (menu option: **CUSTOMER TRIM**)

5.1.1.4.1 Access to menu option CUSTOMER TRIM

Access to the calibration menu is provided by answering **CUSTOMER TRIM?** with **yes** and entering the fixed 3-digit **ACCESS CODE**.

Note:

ACCES CODE to be entered ➡ **987**

Entering an incorrect code will cause skipping to the next option of the configuration menu; another access to CUSTOMER TRIM can only be started after running through the entire configuration menu.

5.1.1.4.2 Old curve / New curve

If the inquiry about the CHARACTERISTIC of the curve is answered by new, the selected trim points are assigned to default data (see 3.2.5).

If a filed curve needs to be corrected or expanded, the above inquiry should be answered by old.

In that case, the trim points already stored will not be affected.

This menu option does not apply if a custom designed curve has not yet been entered.

5.1.1.4.3 Number of trim points

The number of trim points **NUMBER OF TRIM POINTS** can be selected between 2 and 20 (see para. 4.2.2).

5.1.1.4.4 Determining the temperature differential

The **TEMPERATURE DIFFERENCE** setpoint can be set at 3 °C ≤ $\Delta\vartheta$ ≤ 15 °C. The limit conditions defined in para. 4.2.1 shall be observed.

5.1.1.4.5 Automatic calibration

After the TEMPERATURE DIFFERENCE has been determined, the TRIM POINT with the highest number will appear when the first adjustment is made. It corresponds to the number of trim points selected (**TRIM POINT. .**).

The highest flow velocity shall be assigned to that trim point. The flow velocity can be set between 0.00 m/s and 90.00 m/s.

Before starting the automatic calibration by simultaneously pressing ▲ UP and ▼ DOWN, the flow velocity at which the trim point shall be determined must have been available at the sensor for more than 10 seconds.

The heating period required by the measuring procedure is started before the first trim point is set. The remaining heat-up time is displayed in seconds (**REST TIME . . sec.**).

Once the heat-up period is over, the FC01-Ex will start the setting routine for the set flow velocity.

The calibration time is 20 seconds.

Note:

- ❑ Both flow and medium temperature shall be kept constant during that period as otherwise the heating power cannot be correctly determined.

The display will therefore indicate index quantity **xd = ...** for constant flow. During the calibration time of 20 seconds, that quantity should be between -0.10 and +0.10.

Upon completion of the calibration, the program will return to menu option **TRIM POINT . .** with the heating power determined.

The integer value determined will be flashing on the display.

After confirmation, a selection menu is inserted allowing the calibration of the next, same or previous trim point (not with the first trim point).

When the next trim point is selected, the trim point number is reduced by one. The trim point is again assigned to a flow velocity, and the automatic calibration is started.

This procedure is repeated until the last trim point (**TRIM POINT 01**) has been calibrated.

The customer designed characteristic curve has now been established and entered.

5.1.1.4.6 Manual calibration

If a custom designed characteristic curve has already been established and the curve shall be duplicated on an other FC01-Ex, it is possible to enter the data for the various points by hand.

The method is largely identical with that for automatic calibration.

The heating power belonging to the flow velocity is not determined automatically but rather entered on the FC01-Ex by hand.

It is also possible to make the calibration combining automatically determined and theoretically calculated trim points.

5.1.1.4.7 Calibration temperature

After confirmation of the last trim point, **TRIM IS READY!** is displayed.

The second line on the display will show the medium temperature in °C at which the calibration was made. With automatic calibration, the calibration temperature is displayed non-flashing and cannot be changed by hand.

If the calibration data were entered by hand, the calibration temperature must also be set by hand. In that case the temperature value will be flashing.

Note:

- ❑ The medium temperature must be kept constant over the entire calibration process!

5.1.1.4.8 Storing the characteristic curve

Before quitting the CUSTOMER TRIM menu, the FC01-Ex shall be informed whether the custom designed curve determined or entered shall be stored in a permanent (touch switch ★) or volatile way (▲ UP or ▼ DOWN).

If the characteristic curve shall be stored in a volatile way, it will be deleted upon failure or power disconnection.

Note:

- ❑ If a power failure occurs during the calibration, the entire calibration must be repeated!

5.1.1.4.9 Potential errors during the calibration

All errors found during the calibration are indicated with their relevant number.

If one of the following errors occurs, it is not necessary to repeat the entire calibration but rather the calibration of the trim point where the error occurred.

Error	Cause	Rectification
No. 10	Sensor not connected, or cable between FC01-Ex → and sensor defective; or defective sensor	Check cable or replace the pair electronic control unit + monitoring head.
No. 21	Medium temperature too high	
No. 20	Medium temperature too low	
No. 30	Temperature difference selected is too high	Correct temperature difference.

5.1.1.5 Limit switch combinations (menu option: **LIMIT SWITCHES**)

The FC01-Ex comprises two limit switches which are assigned to the physical quantity/quantities to be monitored in menu “LIMIT SWITCHES”.

The following four combinations are available:

* LS1 ⇨ F LS2 ⇨ F
  Limit switch 1 ⇨ flow rate
  Limit switch 2 ⇨ flow rate
* LS1 ⇨ T LS2 ⇨ T
  Limit switch 1 ⇨ medium temperature
  Limit switch 2 ⇨ medium temperature
* LS1 ⇨ F LS2 ⇨ T
  Limit switch 1 ⇨ flow rate
  Limit switch 2 ⇨ medium temperature
* LS1 ⇨ T LS2 ⇨ F
  Limit switch 1 ⇨ medium temperature
  Limit switch 2 ⇨ flow rate

Mode of operation, limit value and hysteresis of the limit switches are set in menu “PARAMETER SELECTION”.

Caution!

⚠ Menu option “LIMIT SWITCHES” may influence data in the parameter selection menu (see para. 5.1.1.14, Quitting the configuration menu).

5.1.1.6 Flow rate unit (menu option: **FLOW UNIT**)

This menu option is used to set the desired flow rate unit:

* METRE/SEC [m/s]
* FEET/SEC. [FPS]
* PERCENT [%]
* BLANK [no unit]

Any further entries relating to flow rate (e.g. limit value, analogue output etc.) refer to that unit.

Standard percent is displayed when BLANK (no unit) is selected.

When the flow rate unit is changed, all configuration and parameter data relating to flow rate will automatically be converted!

5.1.1.7 Medium temperature unit (menu option: **TEMP. UNIT**)

This submenu is used to select medium temperature unit.

Options are:

* GRAD CELSIUS [°C]
* GRAD FAHRENHEIT [°F]
* KELVIN [K]

All other entries relating to the medium temperature (limit value, analogue output etc.) refer to the unit selected there. When the temperature unit is changed, all configuration and parameter data relating to medium temperature will automatically be converted.

5.1.1.8 Display (menu option: **DISPLAY SELECT**)

The FC01-Ex enables the user to define certain points of the display.

When the first line of the LC display in the main menu indicates the flow rate in the unit selected as well as the medium temperature in °C, °F, or K, it is possible to select the 2nd line from the following menu options (see para. 5.1.1.16).

* BARGRAPH	Totalizer:
* LITRE/SECOND [l/s]	* LITRE [l]
* LITRE/MINUTE [l/min]	* METRE^3 [m^3]
* METRE^3/HOUR [m^3/h]	* FEET^3 [F^3]
* GALLONS°/MINUTE	* GALLONS° [° = US-GALLONS]

Where totalizer function has been selected, the totalizer will start at zero counting in the unit selected (litre, m^3 or gallons).

When the display changes from m^3 to litre or gallons, or from litre or gallons to m^3, the value already counted will be converted.

The content of the totalizer is deleted by simultaneously pressing ▲ UP and ▼ DOWN, or when the max. display value (99999999.9 l, m^3 or gallons) is reached. In both cases, the totalizer will restart from zero.

Caution!

⚠ The content of the totalizer is deleted in the event of power failure or disconnection of the power supply!

Skipping to the menu BARGRAPH or PIPE SIZE is effected depending on the selected menu option.

5.1.1.9 Bar graph (menu option: **BARGRAPH**)

This menu option allows the user to set the bar graph as desired. The following settings should be made:

* FLOW / TEMP =	(bar graph assignment: flow rate/medium temperature)
* ZERO =	(initial value of the bar graph)
* FS =	(final value of the bar graph)

Independent of its assignment, the bar graph has a constant resolution of 10 segments.

When entering the initial or final value, the user should observe a reasonable resolution!

The bar graph also comprises the representation of the limit switch(es) as far as they can be indicated in the bar range selected.

The representation of the limit switches in the bar graph depends on the switch-on value of the limit switch.

For representation details see para. 6.2.1 (Operating data)

Example:

Limit switch assignment: LS1 □ F LS2 □ T
Switch-on value LS2: 23 °C
Analogue bar graph assignment: medium temperature
Initial value - analogue bar graph: 20 °C
Final value - analogue bar graph: 30 °C
Instantaneous temperature value: 25 °C
→ resulting in the analogue bar graph display shown below.

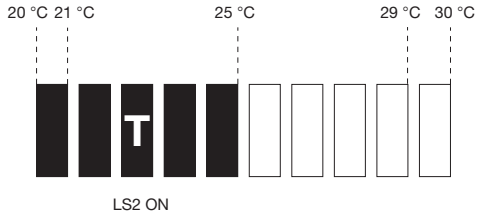


fig. 15

5.1.1.10 Pipe size (menu option: **PIPE SIZE**)

To display a flow volume/time unit or a totalizer function it is necessary to indicate the pipe diameter to calculate mass flow.

This is provided by selecting the pipe diameter in menu option PIPE SIZE comprising pipe diameters from 10.0 to 460.0 mm.

5.1.1.11 Frequency output (menu option: **FREQUENCY OUTPUT**)

The totalizer function of the FC01-Ex has been expanded by the output of **proportional quantity pulses**. The function can only be displayed by version **FC01-Ex-U1T4** (open collector outputs).

The proportional quantity pulses have been determined as follows:

1 pulse / quantity (totalizer unit selected)

Example: 1 pulse / 10.0 [litre]

The frequency output will supply 1 pulse per 10 litres (totalized quantity)

When the quantity-proportional pulses are assigned, the frequency of the frequency output must no exceed 10 Hz. The limits that can be displayed are determined by the flow velocity range and the pipe diameter.

Potential setting range of the frequency output: 1 pulse per 0.1 … 999.9 [litre], [m^3], [Gallons]

Behaviour of the frequency output when the max. frequency is exceeded

The max. frequency being exceeded will not cause the measurement to stop but will rather cause the error output to signal error 60 on the display. This error is included in priority group III.

If a combination of priority III errors occurs simultaneously, they are indicated or stored in the error memory observing the following sequence:

Error No. 20, 30, 31, 60, 40, 41.

Behaviour of the frequency output when the measurement is stopped

When the measurement is stopped (as caused by priority II error and calling the configuration or parameter selection menus), the pulses for the quantity already counted will be available. Thereafter the output of pulses will be stopped, with the frequency output becoming high-resistive until the measurement is restarted.

Behaviour of the frequency output when the content of the totalizer is deleted

The content of the totalizer may be deleted by simultaneously pressing ▲ UP and ▼ DOWN in the main menu

As the frequency output refers to the content of the totalizer, although its operation is not dependent on the content of the totalizer, a totalized quantity that is smaller than that set per pulse will not be lost.

This means that only the content of the totalizer is deleted.

5.1.1.12 Analogue output - flow rate (menu option: **ANA OUT FLOW**)

This menu option allows adjustment of the flow rate analogue output specifically to the requirements of the entire system.

Options are:

* OFFSET = % (FS) (0/4 … 20 mA, 0/1 … 5 V, 0/2 … 10 V)
* ZERO = (initial value 0(20) % corresponds to a flow rate of … [m/s] [%])
* FS = (100% final value corresponds to a flow rate of …[m/s] [%])

When entering the initial value, the user should observe a reasonable resolution!

With a flow volume/time unit selected in menu DISPLAY SELECT and when setting the initial and end values, the pertinent flow volumes will also be indicated.

5.1.1.13 Analogue output - medium temperature (menu option: **ANA OUT TEMP.**)

In conformance with the configuration “Flow rate analogue output” it is possible to adjust the medium temperature analogue output to the requirements of the entire system.

Options are:

* OFFSET = % (FS) (0/4 … 20 mA, 0/1 … 5 V, 0/2 … 10 V)
* ZERO = (initial value 0(20) % corresponds to a medium temperature of … [°C] [°F] [K])
* FS = (final value 100% corresponds to a medium temperature of … [°C] [°F] [K])

When entering the initial or final value, the user should observe a reasonable resolution.

5.1.1.14 Quitting the configuration menu

Upon configuration of the analogue outputs, the menu may be quitted or reset to the start (SENSOR SELECT).

To quit the configuration menu, the controller will check the data entered for plausibility.

“CONFIG. OK!” is indicated when the data are found to be correct. The menu may then be quitted by pressing **M** MODE.

Errors found during the plausibility check are indicated in the following sequence of priority.

Priority of entry errors in the CONFIGURATION menu:

* ERR. A-OUT FLOW OUT OF RANGE
  (flow analogue output outside measuring range)
* ERR. A-OUT FLOW ZERO ≥ FS
  (initial value ≥ final value with flow analogue output)
* ERR. A-OUT TEMP. OUT OF RANGE
  (temperature analogue output outside measuring range)
* ERR. A-OUT TEMP. ZERO ≥ FS
  (initial value ≥ final value with temperature analogue output)
* ERR. BARGRAPH OUT OF RANGE
  (bar value outside measuring range)
* ERR. BARGRAPH ZERO ≥ FS
  (bar initial value ≥ bar final value)

The menu can only be quitted after correction of the error(s). To do this, return to the beginning of the configuration menu by pressing ▼ DOWN or ▲ UP and select the menu option with the incorrect entry for correction.

Caution!

⚠ If during the configuration data are affected which are accessible in the parameter selection menu (which may be the case for the options Medium Selection and Limit Switch Assignment), the option “PARAMETERS” in the main menu will be flashing.

In this event it is imperative to branch into parameter selection menu to set the data in conformance with the desired application.

Example: Changing the limit switch assignment from **LS1 ⇨ F / LS2 ⇨ T** to **LS1 ⇨ F / LS2 ⇨ F**

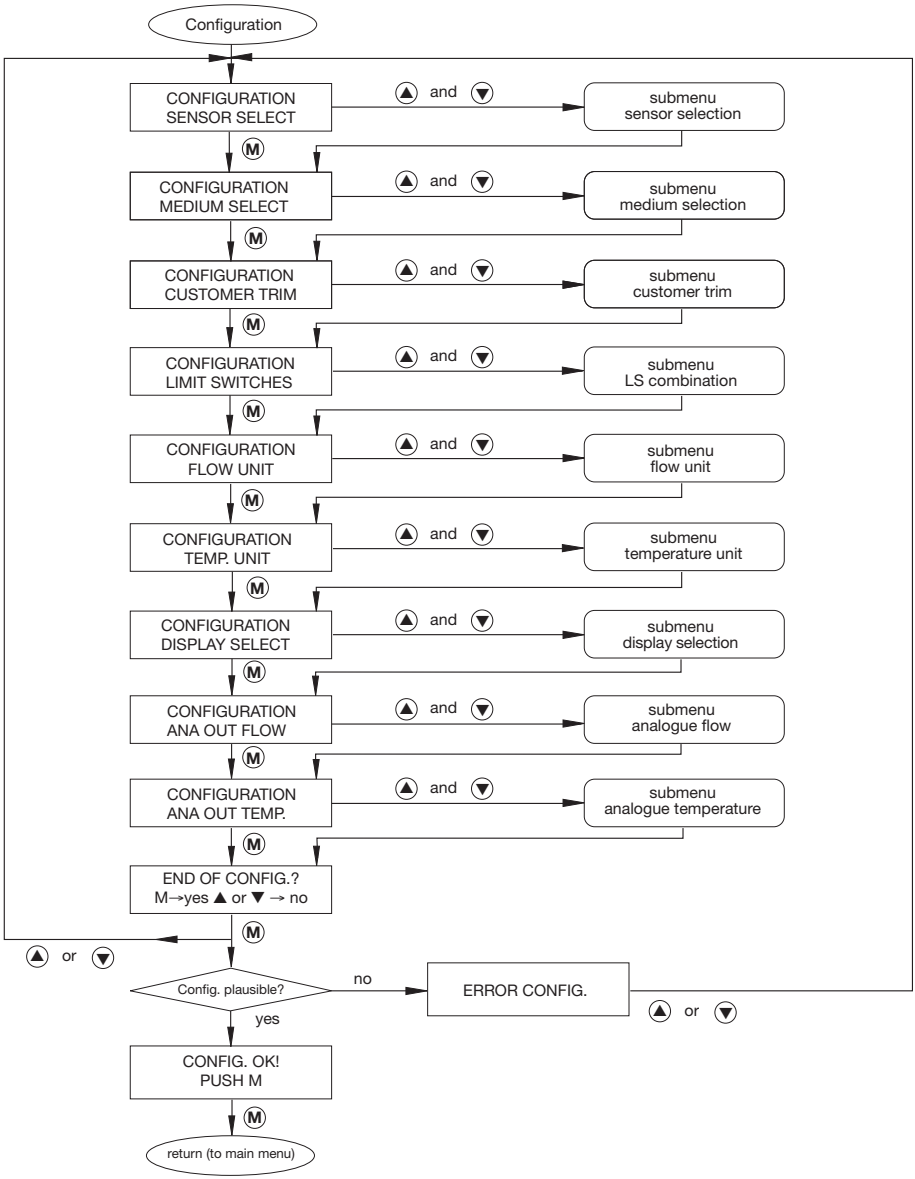
affects **LS2 ON** = 0.00

Parameter data: **LS2 OFF** = end of measuring range

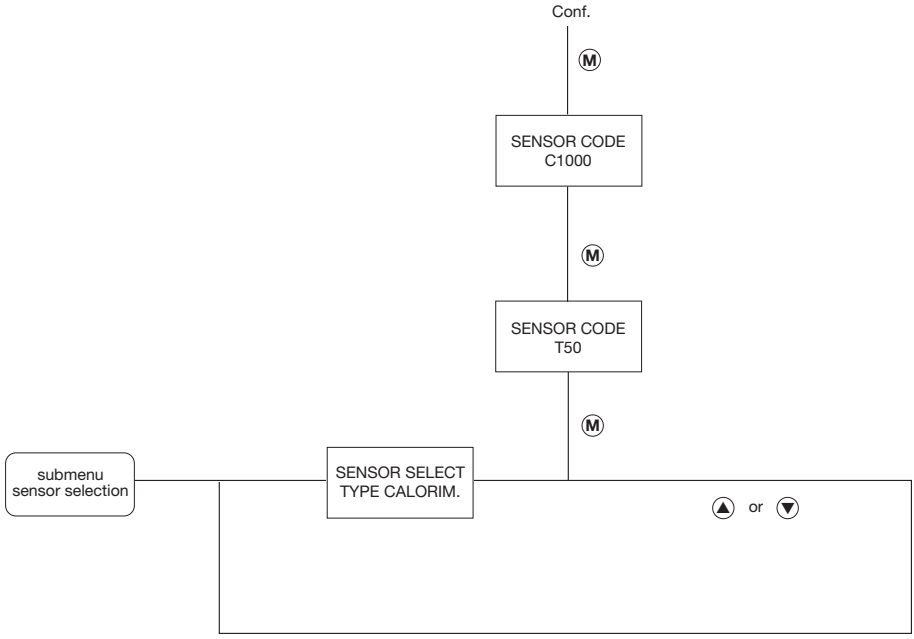
Reason: Changing the physical assignment of limit switch 2 will adjust its switch-on and switch-off values to the new assignment (flow rate).

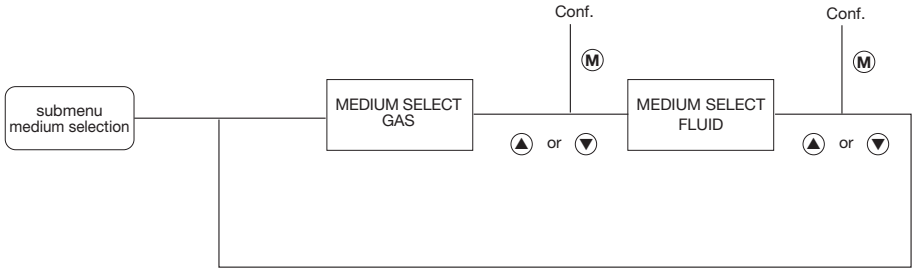
An overview of the configuration menu and a summary of the measuring ranges and menus available for the sensor type selected are shown on the following pages.

5.1.1.15 Configuration menu



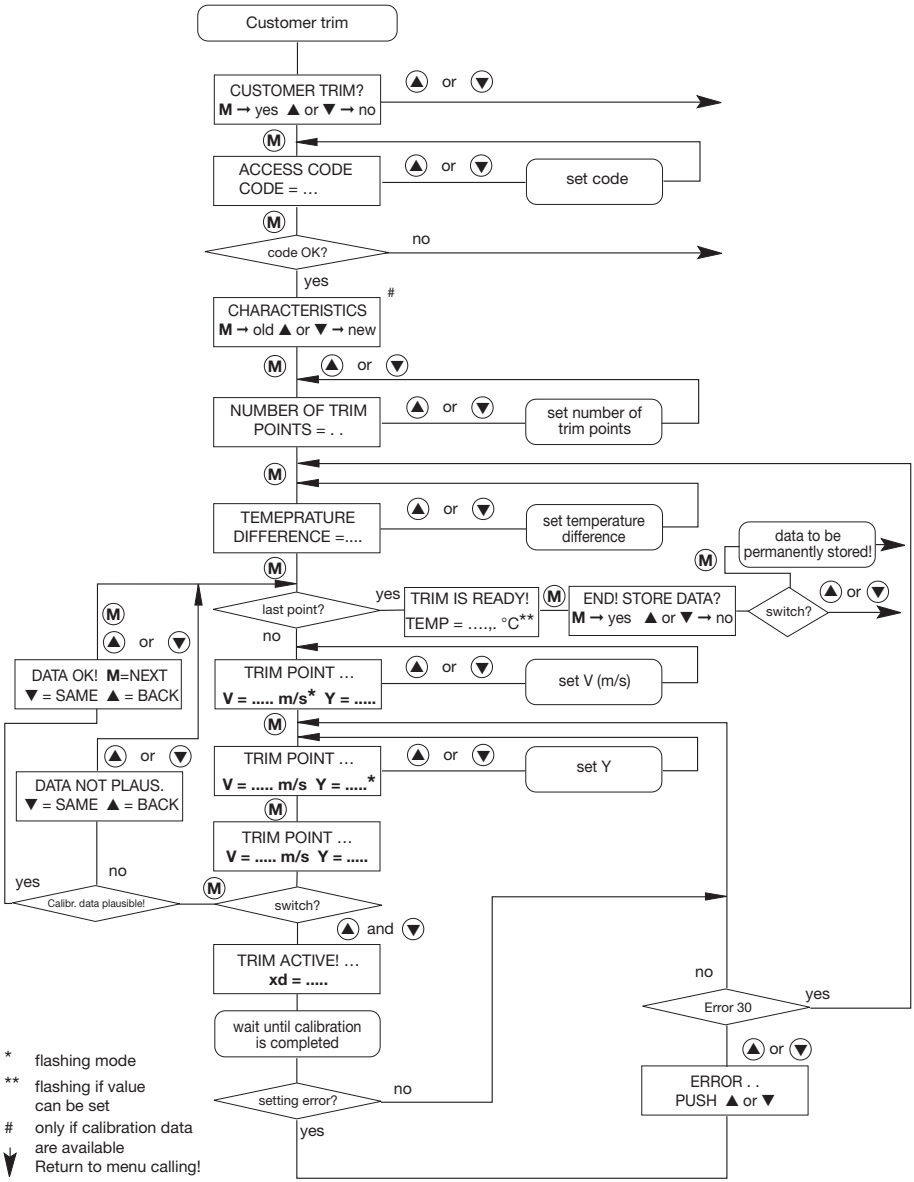
5.1.1.16 Configuration submenus



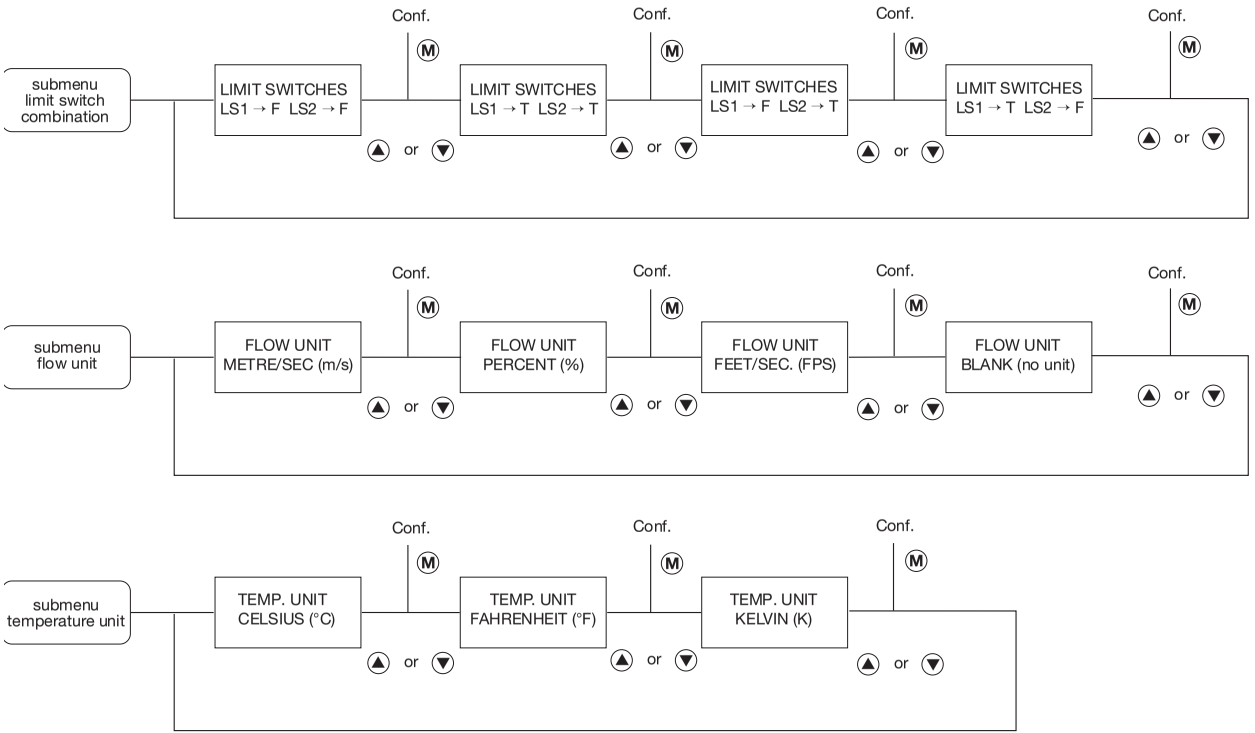


Conf.→ return to configuration menu

Configuration submenu - CUSTOMER TRIM

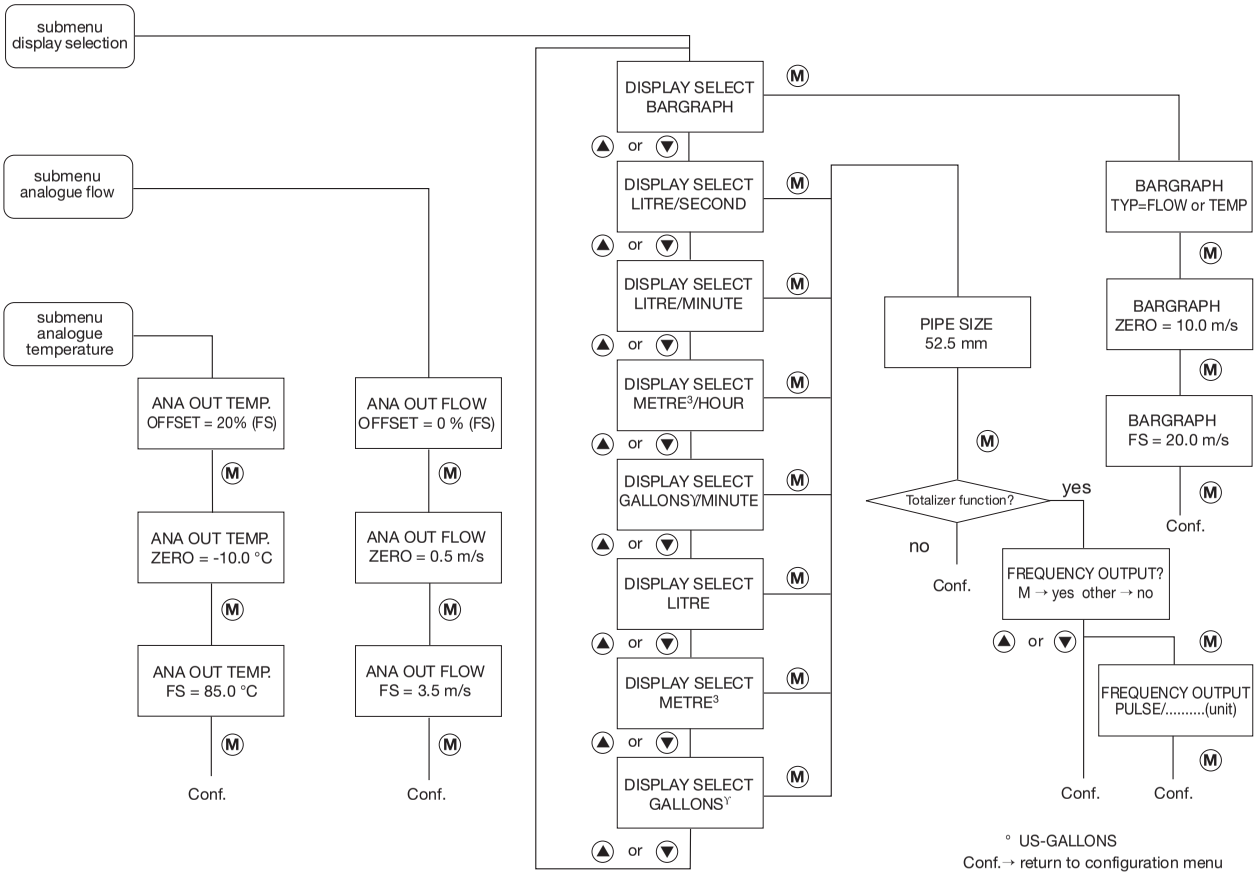


Configuration submenus (cont'd)


submenu limit switch combination
LIMIT SWITCHES LS1 → F LS2 → F
LIMIT SWITCHES LS1 → T LS2 → T
LIMIT SWITCHES LS1 → F LS2 → T
LIMIT SWITCHES LS1 → T LS2 → F
Conf.
M
or
submenu flow unit
FLOW UNIT METRE/SEC (m/s)
FLOW UNIT PERCENT (%)
FLOW UNIT FEET/SEC. (FPS)
FLOW UNIT BLANK (no unit)
submenu temperature unit
TEMP. UNIT CELSIUS (°C)
TEMP. UNIT FAHRENHEIT (°F)
TEMP. UNIT KELVIN (K)

Conf.→ return to configuration menu

Configuration submenus (cont'd)



5.1.2 Parameter selection

After configuration of the FC01-Ex in conformance with its application (configuration menu), it is possible to set parameters (e. g. limit values).

During parameter setting, measuring operations are not possible (see Appendix 1).

The following parameters may be set in the Parameter selection menu:

5.1.2.1 **Measuring time** (menu option: **MEAS. TIME**)

The measuring time can be set between 1 and 30 sec., referring both to flow rate and medium temperature.

The effect of the measuring time may be compared to that of a low-pass filter; it is used to determine the average of the last measured values after each measurement.

The set measuring time does not influence the measuring rate and display up-date.

5.1.2.2 **Limit switch 1 - switch-on value** (menu option: **LS1 ON = ...**)

Limit switch 1 - switch-off value (menu option: **LS1 OFF = ...**)

Depending on the configuration (see configuration menu) limit value 1 may be set either for flow rate or medium temperature.

The limit value may be set over the entire measuring range and is always related to the display value.

Limit switch up-date is by measuring rate, independent of the set measuring time.

The hysteresis is determined by entering different switch-on and switch-off values. Its magnitude should be reasonably adjusted to current operating conditions.

A specific definition of the operation (closed-current or open-circuit principle) may be dropped by separately entering the switch-on and switch-off value of the limit switch, because the definition is deducted from the switch-on and switch-off value.

Example 1: Switch-on value lower than switch-off value

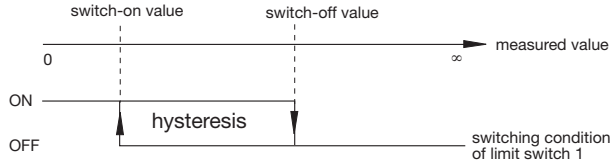


fig. 16

Example 2: Switch-on value higher than switch-off value

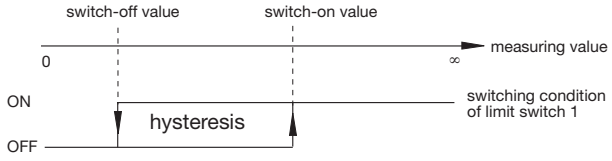


fig. 17

With limit switch 1 set for flow rate and a flow volume/time unit selected in menu DISPLAY SELECT, and when setting the switch-on and switch-off value, the pertinent flow volumes will also be indicated.

5.1.2.3 Limit switch 2 - switch-on value (menu option: **LS2 ON = ...**)
Limit switch 2 - switch-off value (menu option: **LS2 OFF = ...**)

See limit switch 1!

5.1.2.4 Scaling factor (menu option: **FLOWSCALE***)

The scaling factor influences flow rate indication.

The factor, which may be set between 0.01 and 9.99, allows flow rate indication changes (increasing or reducing the measured value in the display).

For example, the scaling factor may be used to indicate the average flow rate in the pipeline rather than that available at the sensor.

5.1.2.5 Quitting the parameter selection menu

Before the parameter menu can be quitted, the controller will conduct a plausibility check of the data entered.

“PARAMETERS OK!” is indicated when the data are found to be correct. The menu may then be quitted by pressing **M** MODE.

Errors found during the plausibility check are indicated in the following sequence of priority.

Priority of entry errors in the PARAMETER SELECTION menu:

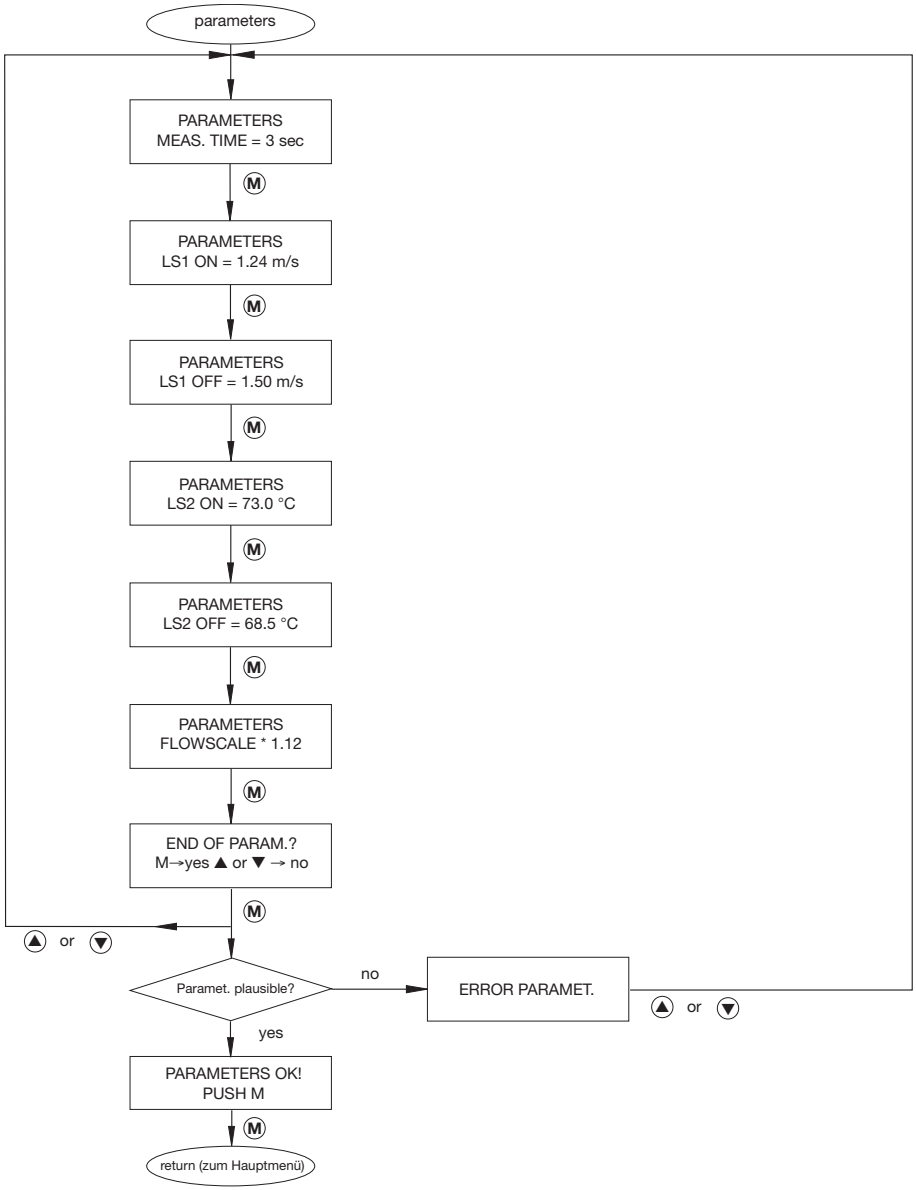
* ERROR LS1 OUT OF RANGE
switch-on and switch-off value for limit switch 1 outside measuring range

* ERROR LS2 OUT OF RANGE
  switch-on and/or switch-off value for limit switch 2 outside measuring range
* ERROR LS1 ON = OFF
  switch-on value for limit switch 1 equals switch-off value for limit switch 1
* ERROR LS2 ON = OFF
  switch-on value for limit switch 2 equals switch-off value for limit switch 2.

The menu can only be quitted after correction of the error(s). To do this, return to the beginning of the parameter selection menu by pressing ▼ DOWN or ▲ UP and select the menu option with the incorrect entry for correction.

An overview of the parameter selection menu is shown on the following page.

5.1.2.6 Parameter selection menu



6 On-line phases

6.1 Switch-on performance

Upon power application, **POWER ON TEST**, will be shown on the display for approx. 1 sec, with the **software version number** being indicated in the second line.

During this period, the integral controller will conduct test routines (see para. 7.1, Test and diagnosis).

If during the test no error was found, the display will indicate **HEATING UP**.

The FC01-Ex will then be in the heating up period required for the measuring procedure.

6.2 Measuring cycle

Upon completion of the heating up period and availability of the first measured value, the display will change to measuring cycle, and the user interfaces such as analogue outputs or limit switches will be up-dated.

The following operating data may be retrieved in the main menu during the measuring cycle:

6.2.1 Operating data

6.2.1.1 Measured value(s)

Flow rate and medium temperature are indicated by the units selected in the upper line of the LC display.

The lower line of the display will optionally show the switching condition of the limit switches and an analogue bar with a 10-segment resolution, or the flow volume/time unit pertinent to the indicated flow rate or the totalized flow volume (totalizer function).

The analogue bar has different meanings, depending on its configuration (see para. 5.1.1.9 - menu option BARGRAPH).

The limit switches are identified according to their physical assignment, i.e. by **F** for flow rate and **T** for medium temperature, at the first or last place of the second line on the display.

If **F** and **T** are shown reversed, the limit switch is in the switch-on condition.

Limit switches lying within the analogue bar range are also represented at the appropriate place of the analogue bar (see para. 5.1.1.9).

The following figures show the display variants under the menu option “Measured value(s)” (para 5.1.1.8 - menu option DISPLAY SELECT and 5.1.1.11 - menu option FREQUENCY OUTPUT).

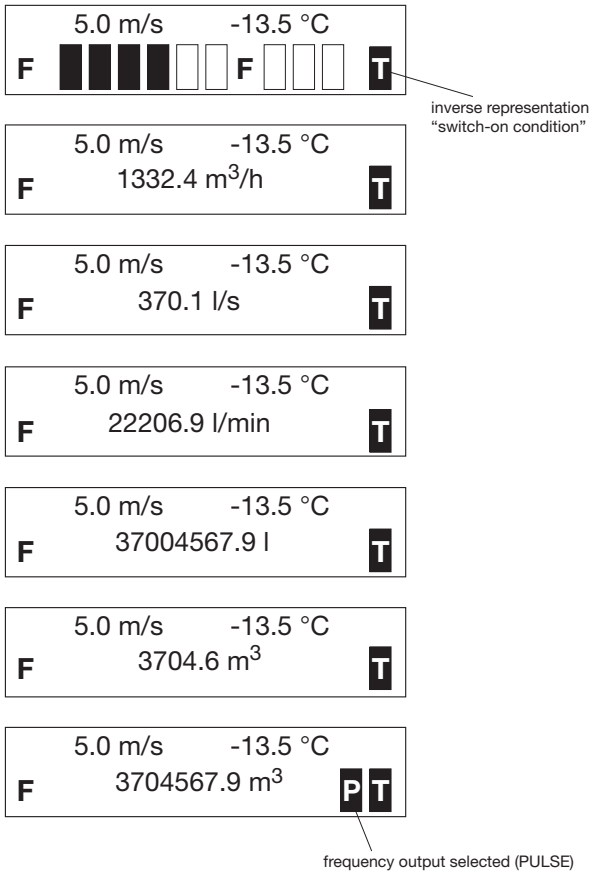


fig. 18

6.2.1.2 Peak values (menu option: **PEAK VALUE MIN / PEAK VALUE MAX**)

The FC01-Ex comprises four specific measured-values memories.

They store the lowest and highest value of flow rate and medium temperature.

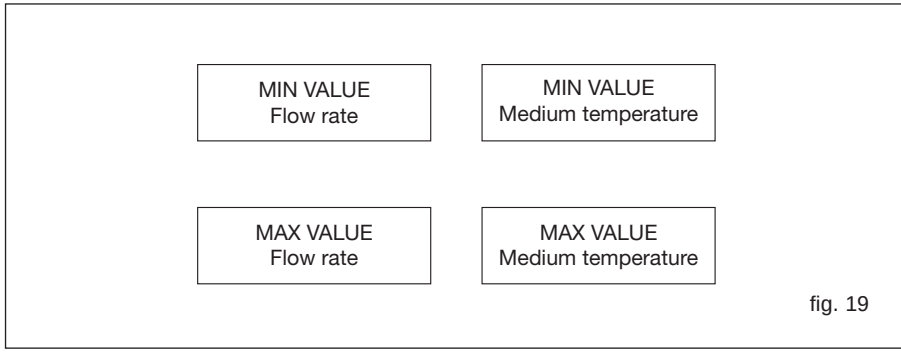


fig. 19

After switch-on or NOT-BUSY indication, the minimum and maximum values are deleted and will be continuously updated (non-return pointer principle).

The peak values may be retrieved in the main menu and are deleted by simultaneously pressing ▲ UP and ▼ DOWN.

Caution!

⚠ Power failure or disconnection of the power supply will delete the contents of the four measured-values memories.

6.2.1.3 Last error (menu option: **LAST ERROR**)

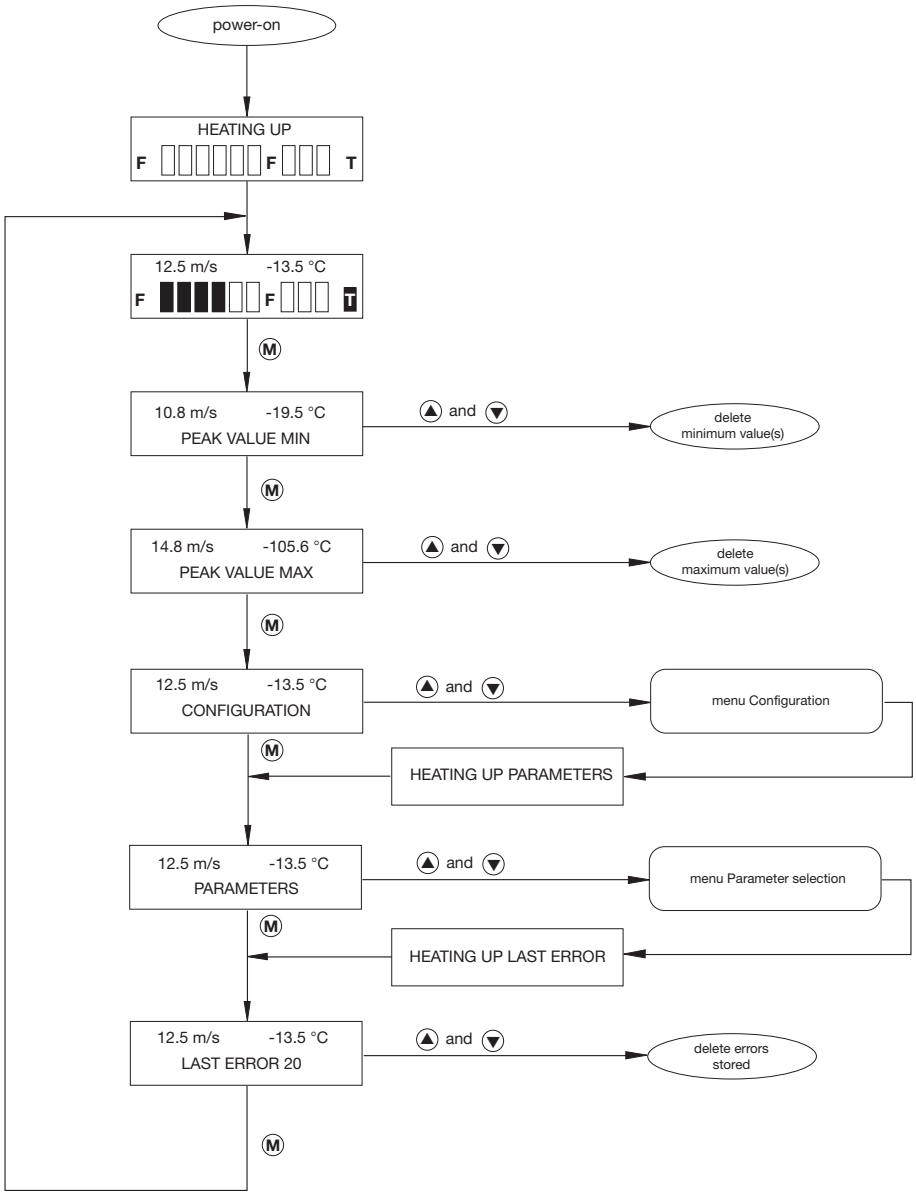
The last main menu option to be called is the error memory.

This error memory comprises the number of the last error (see section 7). It may be very helpful when commissioning the FC01-Ex.

Other than the peak value memories described above, the contents of this memory will be retained even upon failure.

The user may purposely delete the error memory in the condition selected by simultaneously pressing ▲ UP and ▼ DOWN.

6.2.1.4 Main menu



7 Errors

7.1 Test and diagnosis

The FC01-Ex is provided with extensive test and diagnosis functions which may be classified as follows.

7.1.1 Priority group I

Priority group I comprises the switch-on test routines (FC01-Ex self-test) which are carried out when the system is switched on.

Their implementation is indicated.

Errors No. 1 to 5 do not allow system operation.

The test routines may be repeated by pressing any of the switches.

If even after several trials the switch-on test cannot be conducted without error indication, the system should be returned to the supplier for rectification, indicating the error number.

Priority I errors cannot be rectified by the user!

7.1.2 Priority group II

These test functions are also continuously carried out during operation. The occurrence of errors No. 50, 10 and 21 will cause measurements to stop, indicating the error and monitoring the source of the error. Upon rectification of the error, the system will automatically return to measuring operation.

7.1.3 Priority group III

These test routines are also continuously carried out during operation.

Other than the above priority groups, errors No. 20, 30, 31, 60, 40 and 41 will not cause measurements to stop; the error output will indicate and the number of the error will be shown on the display.

7.2 Potential errors

Independent of the priority group, all errors found are indicated with their relevant number.

In order to facilitate operation, the last error is stored in a non-volatile memory. The stored error may be retrieved and deleted in the main menu.

If a combination of errors occurs simultaneously, they are indicated or stored in the error memory observing the following sequence.

Priority group I

Error	Cause	Rectification
No. 1	No system parameters available	return to supplier
No. 2	Incorrect test sum of parameter memory	return to supplier
No. 3	Incorrect test sum of program memory	return to supplier
No. 4	Incorrect test sum of data memory	return to supplier
No. 5	Internal controller error	return to supplier

Priority group II

Error	Cause	Rectification
No. 50	No adjustment data available	carry out custom designed adjustment
No. 10	Sensor not connected; or cable between FC01-Ex and sensor defective; or defective sensor	check cable or replace sensor
No. 21	Medium temperature too high	

Priority group III

Error	Cause	Rectification
No. 20	Medium temperature too low	
No. 30	Over limits of flow rate	
No. 31	Measuring range of flow velocity below limits (V < (1st trim point - 10%))	
No. 60	Assignment of quantity per pulse too low*	
No. 40	Controller error (oscillator-watchdog)	
	Admissible EMC levels may have been exceeded	
No. 41	Controller error (watchdog-timer)	
	Admissible EMC levels may have been exceeded	

* Error No. 60 can only occur with version FC01-Ex-U1T4.

8 Technical data

8.1 Ambient conditions FC01-Ex

Storage temperature:	- 20 ... +70 °C
Ambient temperature: *	+10 ... +43 °C
Degree of protection:	IP54

*Only if the modules are spaced at least 10 mm.

8.2 Monitoring head CST-Ex

Temperature measuring range I (medium):	-40 ... +75 °C
Temperature measuring range II (sensor):	-30 ... +75 °C
Temperature measuring range III (cable):	-10 ... +80 °C
Pressure resistance:	100 bar (1470 PSI)
Degree of protection (housing)	IP67 (connection cable in locked condition)
Pollution degree (cable/head connection) (to DIN VDE 0627)	2

8.3 Electrical characteristics

8.3.1 Power supply

DC supply

Pin selection:

Signal name	Pin XV
$+U_V$	2
$-U_V$	3

8.3.1.1 DC voltage supply

Supply voltage:	U_{VN} = 24 V
Input voltage range: (ripple incl.)	U_V = 19 V to 32 V (12 V only possible with voltage output)
Admissible ripple:	w = 20 % U_V
Rated current consumption:	
analogue outputs V1 and V2:	I_{vnk} = 170 mA ± 10 % with zero flow
	I_{vnk} = 200 mA ± 10 % with max. flow (end of measuring range)
analogue output C1:	I_{vnk} = 185 mA ± 10 % with zero flow
	I_{vnk} = 230 mA ± 10 % with max. flow (end of measuring range)
Inrush current:	I_p = 3 A (20 µs)
Switch-off current:	I_{kipp} = 0.75 A
Rated power consumption:	P_n = 4.1 W (with zero flow) voltage outputs
	P_n = 4.8 W with max. flow (end of measuring range) voltage outputs
Insulation voltage:	supply input - central electronic unit ≥ 500 V

8.4 Analogue outputs

The analogue outputs are physically isolated from each other and from the electronic control unit FC01-Ex.

Pin selection for analogue outputs V1, V2 and C1

Signal name	Pin XAO
NC	1
Analogue output 1 - flow	2
Reference ground 1	3
Shield for analogue output 1 *	4
Shield for analogue output 2 *	5
Analogue output 2 - temperature	6
Reference ground 2	7
NC	8

NC - not used

Analogue output 1 - ANA OUT FLOW (flow output)
Analogue output 2 - ANA OUT TEMP. (temperature output)

*** Shield ungrounded - apply one side only.**

Insulation voltage:
- analogue output - analogue output 500 V
- analogue output - central electronic unit 500 V
- shield potential - supply voltage of analogue output ≤ 48 V DC

8.4.1 Voltage output V1 - 5 V FS

Signal voltage range:	U_S = 0 V to 5 V ± 2% FS
Max. signal ripple:	dU_S = 5% FS
Min. admissible load resistance:	R_l = 1 k⏐
Max. admissible load capacity:	C_l = 1 nF
Max. admissible load inductance:	L_l = 100 nH
Short-circuit proof:	yes (XAO - between all terminals)

8.4.2 Voltage output V2 - 10 V FS

Signal voltage range:	U_S = 0 V to 10 V ± 2% FS
Max. signal ripple:	dU_S = 5% FS
Min. admissible load resistance:	R_l = 2 k⏐
Max. admissible load capacity:	C_l = 1 nF
Max. admissible load inductance:	L_l = 100 nH
Short-circuit proof:	yes (XAO - between all terminals)

8.4.3 Current output C1 - 20 mA FS

Signal current range:	I_S = 0 mA to 20 mA ± 2% FS
Max. signal ripple:	dI_S = 5% FS
Min. admissible load resistance:	R_l = 0 Ω
Max. admissible load resistance:	R_l = 250 Ω

8.5 Signal outputs

The signal output channels are physically isolated from each other and from the electronic control unit FC01-Ex.

8.5.1 Relay outputs (change over contacts, DC or AC switching voltage)

Pin selection:	Signal name	Pin XAH
	Limit Switch 1 / shield	1
	Limit Switch 1 / N/O	2
	Limit Switch 1 / common	3
	Limit Switch 1 / N/C	4
	Limit Switch 2 / shield	5
	Limit Switch 2 / N/O	6
	Limit Switch 2 / common	7
	Limit Switch 2 / N/C	8

Resistive load

Max. admissible switching capacity:	50 W
Max. admissible switching current:	1 A
Max. admissible continuous current:	1 A
Max. admissible switching voltage:	50 V
Contact life at 1 A:	3 x 10^5 cycles

Inductive load - with safety circuit - AC voltage

Max. admissible switching capacity:	125 VA
Max. admissible switching current:	1.25 A
Max. admissible continuous current:	1.25 A
Max. admissible switching voltage:	100 V
Contact life cos φ = 0.5:	2.4 x 10^5 cycles
Insulation voltage:	signal contact - central electronic unit 500 V
	signal contact - signal contact 500 V

8.5.2 Open collector outputs (DC switching voltage)

Pin selection:	Signal name	Pin XAH	Polarity
	/ ERROR emitter	1	-
	/ ERROR collector	2	+
	/ BUSY / PULSE emitter	3	-
	/ BUSY / PULSE collector	4	+
	Limit Switch 2 emitter	5	-
	Limit Switch 2 collector	6	+
	Limit Switch 1 emitter	7	-
	Limit Switch 1 collector	8	+

Voltage level

Low level - active:	U_{ce} < 0,8 V for I_C < 10 mA
	U_{ce} < 1 V for I_C < 100 mA
High level - passive:	U_{ce} < 48 V
	$U_{ce\ max}$ = 60 V
	max. leakage current ≤ 25 µA
Reverse polarity protection:	yes - I_{max} < 1 A
Short-circuit protection:	yes - I_{max} < 1 A

Resistive load

Max. admissible switching capacity:	1.5 W
Max. admissible switching current:	150 mA
Max. admissible switching voltage:	36 V

Inductive load - L < 100 mH
(DC voltage - without external safety capacity)

Max. admissible switching capacity:	1.5 VA
Max. admissible switching current:	40 mA
Max. admissible switching voltage:	36 V

Capacitive Last - C < 20 µF

Max. admissible switching capacity:	1.5 VA
Max. admissible switching current:	1.5 A
Max. admissible switching voltage:	36 V
Insulation voltage:	signal input - central electronic unit 500 V signal input - signal input 500 V

8.6 Metrological data

8.6.1 Mass flow measurement:

Medium:	air	water
Measuring range:	0 … 20 m/s	0 … 3 m/s
Accuracy:	± 10% MBE * [1)]	±10% MBE *
Repeatability: (5% MBE – 100% MBE)	± 1% MW **	±1% MW **

8.6.2 Temperature measurement:

Measuring range:	-40 … +90 °C	0 … +90 °C
Accuracy:	± 1% MB ***	± 1.5% MB ***

8.6.3 FC01-Ex Electronic control unit

Temperature drift of the electronic control unit:	± 0.1%/K/MBE *	± 0.35%/K/MBE *
Warm-up to full accuracy:	15 min	15 min

* MBE - of final value
** MW - measured value
*** MB - measuring range
1) Please enquire for higher accuracy

8.7 Sensor interface - Electrical data

Terminal	Mnemonics	Data
XSK1	R(HEIZ)-LO	Function: terminal for negative pole of heater element Drain output of heating current control Max. sink-current: I_{sink} = 88 mA Dielectric strength: -0.5 V … +20 V DC
XSK2	R(HEIZ)-HI	Function: terminal for positive pole of heater element Hi-potential of heater source Output voltage range (load dependent) U_a = 21 V … 24 V DC Max. current output: I_{max} = 100 mA Not short-circuit proof
XSK3	R(Tref)-HI	Function: terminal for positive RTD pole for medium temperature measurement Input resistance: > 1 G⏐ Dielectric strength: -17 V … +30 V DC
XSK4	R(Tref)-LO	Function: terminal for positive RTD pole for medium temperature measurement Input resistance: > 1 G⏐ Dielectric strength: -17 V … +30 V DC
XSK5	AGND	Function: analogue ground Reference potential of exitation current source for RTD operation
XSK6	IS	Function: output of exitation current source for RTD operation Exitation current: 1 mA ± 1% Admissible load range: R_{load} = 0 … 2 k⏐ Dielectric strength: ±15 V DC
XSK7 XSK8	SGND	Function: shield ground Terminals for sensor cable shielding
XSK9	R(Tdiff)-LO	Function: terminal for negative pole of the heated RTD Input resistance: > 1 G⏐ Dielectric strength: -17 V … +30 V DC
XSK10	R(Tdiff)-HI	Function: terminal for positive pole of the heated RTD Input resistance: > 1 G⏐ Dielectric strength: -17 V … +30 V DC

9 Examples

9.1 Example 1: Calorimetric monitoring head- Medium water - New curve

Task definition

The FC01-Ex with calorimetric monitoring head shall be used to control a water cooling cycle.

The flow velocity to be controlled and measured lies between 0.00 m/s and 1.80 m/s at a constant medium temperature of approx. +82 °C.

A flow meter to be used as a reference instrument is available on loan.

Approach

As the accuracy does not need to be very high (±5%), it is supposed that 10 trim points are required to provide a satisfactory solution. To obtain a higher accuracy, the number of trim points can be increased to 20.

The distribution of the 10 trim points should be linear over the entire measuring range.

Implementation

Select the calorimetric sensor in submenu **SENSOR SELECT** and the medium **FLUID** in submenu **MEDIUM SELECT** before making the custom designed calibration.

Enter 1023 (marked on sensor) as C value to define the sensor-specific tolerances. The T value is a code for the temperature sensitivity of the sensor and needn't be taken into account for this application. The preset value of 50 is transferred.

After entering and confirming the sensor-specific data, press ▲ UP and ▼ DOWN in order to branch into menu **CUSTOMER TRIM**.

The settings required for the custom-designed calibration start after the 3-digit code - **ACCES CODE** - (see para. 5.1.1.4.1) has been entered.

As an already filed custom-designed curve has to be completely overwritten, the inquiry about the **CHARACTERISTICS** of the curve shall be answered by **new**. In that case, the trim points selected are pre-assigned to data (see para. 4.2.5).

Enter **10** as the **NUMBER OF TRIM POINTS** by pressing ▲ UP and ▼ DOWN.

The temperature difference setpoint - **TEMPERATURE DIFFERENCE** - is shown in the table of para. 4.2.1 where a temperature difference of 3.3 °C is indicated for water in this flow velocity range.

As in this example a new custom-designed curve is to be determined, it is necessary to assign the max. flow velocity (1.80 m/s) to trim point 10. The remaining trim points (9 …1) are automatically and linearly assigned as follows:

Trim point	V [m/s]					
10	1.80					
9	**1.60**					
8	**1.40**					
7	**1.20**					
6	**1.00**					
5	**0.80**					
4	**0.60**					
3	**0.40**					
2	**0.20**					
1	**0.00**					

After trim point 10 has been set at 1.80 m/s and the velocity has actually been controlled accordingly, automatic calibration is started by simultaneously pressing ▲ UP and ▼ DOWN.

The following **Y** value was determined for flow velocity 1.80 m/s after completion of the heating up period and the calibration.

Trim point	V [m/s]	Y				
10	1.80	**35400**				
9	1.60					
8	1.40					
7	1.20					
6	1.00					
5	0.80					
4	0.60					
3	0.40					
2	0.20					
1	0.00					

This value represents the heating power required to measure the velocity of 1.80 m/s.

After this value has been transferred, trim points 9 ... 1 should be processed the same way.

The **Y** values shown in the following table were measured for trim points 9 ... 1.

The medium temperature at which the calibration was made (here: **TRIM IS READY! TEMP = 82.8 °C**) is indicated on the display after the last trim point.

The CUSTOMER TRIM procedure is now completed !

Trim point	V [m/s]	Y				
10	1.80	35400				
9	1.60	**35267**				
8	1.40	**35158**				
7	1.20	**35063**				
6	1.00	**34890**				
5	0.80	**34668**				
4	0.60	**34347**				
3	0.40	**33846**				
2	0.20	**32957**				
1	0.00	**24635**				

Before quitting the submenu, the calibration data shall be permanently stored by pressing **M**.

Verification of the solution

In order to verify the curve determined, again set the flow velocity at the various trim points and compare it to the values indicated by the FC01-Ex during the measuring operation.

Test values are:

Trim point	V [m/s]	Y	V [m/s] Test data	Deviation [%MBE*]	
10	1.80	35400	**1.94**	**-7.78**	
9	1.60	35267	**1.67**	**-3.89**	
8	1.40	35158	**1.38**	**1.11**	
7	1.20	35063	**1.18**	**1.11**	
6	1.00	34890	**0.99**	**0.56**	
5	0.80	34668	**0.80**	**0.00**	
4	0.60	34347	**0.61**	**-0.56**	
3	0.40	33846	**0.42**	**-1.11**	
2	0.20	32957	**0.21**	**-0.56**	
1	0.00	24635	**0.01**	**-0.56**	

The verification of the trim points indicates that trim point 10 is outside the tolerance required.

One of the reasons may be that the flow velocity varied when point 10 was set.

To increase the accuracy at a velocity of 1.80 m/s, that trim point should be redetermined.

* MBE = upper measuring range value

Correction of the characteristic curve

To correct a custom designed curve branch into menu **CUSTOMER TRIM** the same way as when determining the curve.

The inquiry about the **CHARACTERISTIC** shall be answered by **old** as the curve filed is largely maintained, with only point 10 being corrected.

All other data (trim points, temperature difference) remain unchanged and are transferred by pressing **M**.

The set flow velocity (1.80 m/s) is confirmed at trim point 10 and the automatic calibration as described under **Implementation** is started.

The **Y** value for a flow velocity of 1.80 m/s is shown in the following table.

Trim point	V [m/s]	Y				
10	1.80	**35346**				

The corrected value is transferred!

All other calibration data remain unchanged and shall be confirmed by pressing **M** until the end of the calibration menu is reached.

Another verification of the characteristic curve will show the following test values:

Trim point	V [m/s]	Y	V [m/s] Test data	Deviation [%MBE]	
10	1.80	35346	**1.85**	**-2.78**	
9	1.60	35267	**1.67**	**-3.89**	
8	1.40	35158	**1.38**	**1.11**	
7	1.20	35063	**1.18**	**1.11**	
6	1.00	34890	**0.99**	**0.56**	
5	0.80	34668	**0.80**	**0.00**	
4	0.60	34347	**0.61**	**-0.56**	
3	0.40	33846	**0.42**	**-1.11**	
2	0.20	32957	**0.21**	**-0.56**	
1	0.00	24635	**0.01**	**-0.56**	

The example shows that after being corrected, trim point 10 is within the required tolerance of ±5%.

Expansion of the characteristic curve

By following the instructions of para. 4.2.7 an existing curve can also be expanded upward.

In application example 1, the flow velocity range shall be increased by 0.30 m/s. This means that two additional trim points are required: at 1.95 m/s and at 2.10 m/s.

To do this, branch into menu CUSTOMER TRIM and enter old because the existing curve shall not be deleted but rather be expanded.

Increase the number of trim points from 10 to 12. Do not change the temperature difference, leave it at 3.3 °C!

Then assign flow velocity 2.10 m/s to trim point 12 (for ease of usage it had already been pre-assigned with 1.82 m/s) and start the automatic calibration. After determination of the **Y** value for point 12, trim point 11 is assigned to a velocity of 1.95 m/s (it had already been pre-assigned to 1.81 m/s) and the automatic calibration is started..

All other data remain unchanged and shall be confirmed by pressing **M** until the end of the CUSTOMER TRIM menu is reached.

Trim point	V [m/s]	Y				
12	**2.10**	**35441**				
11	**1.95**	**35396**				
10	1.80	35346				
9	1.60	35267				
8	1.40	35158				
7	1.20	35063				
6	1.00	34890				
5	0.80	34668				
4	0.60	34347				
3	0.40	33846				
2	0.20	32957				
1	0.00	24635				

Manual entry of a characteristic curve

It is also possible to enter a custom designed curve by means of the keyboard.

This may be reasonable when several FC01-Ex flow meters are used under identical conditions (medium, installation etc.).

To duplicate the expanded curve of example 1 on a second FC01-Ex, select the calorimetric sensor in menu **SENSOR SELECT**, set its C value and enter **FLUID** in menu MEDIUM SELECT.

For other entries proceed as described for example 1 (Implementation).

CHARACTERISTIC	□	new
NUMBER OF TRIM POINTS	□	12
TEMPERATURE DIFFERENCE	□	3.3

Take the data for the curve from the table of page 71 and set them on the FC01-Ex.

Flow velocity 2.10 m/s shall be assigned to trim point 12. Other than with the automatic calibration the applicable **Y** value of 35441 shall be entered by means of the keyboard. 1.95 m/s and 35396 are set for point 11 etc.

The procedure is repeated until the entire curve has been determined.

After the data for point 1 have been entered and confirmed, the display indicates **TRIM IS READY! TEMP = 25.0 °C**.

Other than with the automatic calibration, the calibration temperature at which the curve has been determined will be flashing on the display and must be set at +82.8 °C by hand (example 1 “Implementation”).

The calibration data are completely entered!

Before quitting the submenu, press **M to** permanently store the calibration data.

9.2 Example 2: Distribution of trim points

Task definition

The FC01-Ex with calorimetric sensor shall be used to measure air flowing at a max. velocity of 25 m/s.

The lower measuring range value is approx. 0 m/s. A calibrated calorimetric metering pipe is used as a reference. The pertinent measuring instrument indicates the flow velocity in m/s.

The measuring range of the reference instrument is specified between 1 m/s and 40 m/s; the measuring error shall be 1% of the value measured.

The resultant error shall be < 3% of the upper measuring range value.

A**pproach / Implementation**

With a disturbance-free flow profile, the trim points can be calculated by the following formula:

$AB = MA + (MB \times (1 - e^{-(((SP-1) \times g)/SG)}))$

$g = 2.5 \times (SP - 1)/SG$

AB - trim value [m/s]

MA - lower measuring range value [m/s] = 0 m/s

ME - upper measuring range value [m/s] = 25 m/s

MB - measuring range [m/s]

$MB = ME - MA = 25$ m/s

SP - trim point no.

SG - total number of trim points = 16

g - distribution coefficient

Determine the trim points using the above formulas.

V_{lin} shows the alternative linear trim point selection.

Verification

Projecting the suggested trim points on to the standard curve used by E-T-A will result in max. error being 0.5% MBE. This is clearly below the required ± 3% MBE (0.75 m/s).

With a linear trim point distribution, max. error would be 2.4%. This would also be a satisfactory solution, with the advantage that you needn't calculate the trim points.

SP No.	g	V [m/s]		V_{lin} [m/s]
16		**25.00**	set at upper measuring range value	**25.00**
15	2.19	**21.31**		**23.33**
14	2.03	**20.20**		**21.66**
13	1.88	**18.87**		**20.00**
12	1.72	**17.33**		**18.33**
11	1.56	**15.58**		**16.66**
10	1.41	**13.67**		**15.00**
9	1.25	**11.62**		**13.33**
8	1.09	**9.51**		**11.66**
7	0.94	**8.41**		**10.00**
6	0.78	**5.42**		**8.33**
5	0.63	**3.62**		**6.66**
4	0.47	**2.10**		**5.00**
3	0.31	**0.96**		**3.33**
2	0.16	**0.24**		**1.66**
1		**0.00**	set at zero	**0.00**

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Appendix 1 - Performance of the digital and analogue outputs during the operating and error modes

Duty/ Error status	LIMIT SWITCH 1	LIMIT SWITCH 2	NO ERROR	NOT BUSY and FREQUENCY OUTPUT	ANA OUT FLOW	ANA OUT TEMP.
Start-up (reset)	ON	ON	ON	ON	MAX	MAX
Start-up test active	OFF	OFF	OFF	OFF	MIN	MIN
Error No. 1	OFF	OFF	OFF	OFF	MIN	MIN
Error No. 2	OFF	OFF	OFF	OFF	MIN	MIN
Error No. 3	OFF	OFF	OFF	OFF	MIN	MIN
Error No. 4	OFF	OFF	OFF	OFF	MIN	MIN
Error No. 5	OFF	OFF	OFF	OFF	MIN	MIN
Heating period active	OFF	OFF	ON	OFF	MIN	MIN
Normal duty	**X**	**X**	**ON**	**ON**	**X**	**X**
Configuration active	OFF	OFF	ON	OFF	MIN	MIN
Parameter selection active	OFF	OFF	ON	OFF	MIN	MIN
Error No. 50	OFF	OFF	OFF	OFF	MIN	MIN
Error No. 10	OFF	OFF	OFF	OFF	MIN	MIN
Error No. 20	X	X	OFF	ON	X	X
Error No. 21	OFF	OFF	OFF	OFF	MIN	MIN
Error No. 30	X	X	OFF	ON	X	X
Error No. 31	X	X	OFF	ON	X	X
Error No. 60 *	X	X	OFF	FA	X	X
Error No. 40	X	X	Y	ON	X	X
Error No. 41	X	X	Y	ON	X	X

X = standard performance
Y = OFF pulse
FA = frequency output 10 Hz

* When frequency output has been selected.

Note: The occurrence of error No. 40/41 will always cause an internal reset.
Status of the outputs prior to the error status described → see start-up (reset)

Prüf- und Zertifizierungsstelle ZELM Ex

·C·E·R·T·I·F·I·C·A·T·E·

(1) **Production Quality Assurance Notification (Translation)**

(2) Equipment and Protective Systems Intended for Use in Potentially Explosive Atmospheres - **Directive 94/9/EC**

(3) Notification Number: **ZELM 02 ATEX 1121**

(4) Product group(s): Electromechanical and electronical switch, protection and control equipment and recorders in the decisive type of protection intrinsic safety "i".

A list of the EC-Type Examination Certificates covered by this notification is held by the notified body.

(5) Applicant: **E-T-A Elektrotechnische Apparate GmbH**
Industriestraße 2-8
D-90518 Altdorf

(6) Actual manufacturer: **E-T-A Elektrotechnische Apparate GmbH**
Industriestraße 2-8
D-90518 Altdorf

(7) The Prüf- und Zertifizierungsstelle ZELM Ex, notified body No. 0820 for Annex IV in accordance with Article 9 of the Council Directive 94/9/EC of 23 March 1994, notifies to the applicant that the actual manufacturer has a production quality system which complies to the Annex IV of the Directive.

(8) This notification is based on the confidential audit report No. AB 0212001, issued the 12.12.2002. This notification is valid until 11.12.2005 and can be withdrawn if the actual manufacturer no longer satisfies to the requirements of Annex IV.

Results of periodical reassessment of the quality system production within the period of validity are a part of this notification.

(9) According to Article 10 (1) of the Directive 94/9/EC the CE-Marking shall be followed by the identification number 0820 of ZELM Ex as the notified body which is involved in the production control stage.

Zertifizierungsstelle **ZELM Ex**

Dipl.-Ing. Harald Zelm

Zertifizierungs- und Prüf- stelle ZELM Ex

Braunschweig, December 18, 2002

Deutscher Akkreditierungs Rat DAR
ZLS-ZQ-117/99

Notifications without signature and stamp are not valid. The notification may only be circulated without alteration. Extracts or alterations are subject to approval by the Prüf- und Zertifizierungsstelle ZELM Ex. In the case of dispute, the German text shall prevail.

Prüf- und Zertifizierungsstelle ZELM Ex • Siekgraben 56 • D-38124 Braunschweig

Prüf- und Zertifizierungsstelle

ZELM Ex

(1) # EG-Baumusterprüfbescheinigung

(2) Geräte und Schutzsysteme zur bestimmungsgemäßen Verwendung in explosionsgefährdeten Bereichen – **Richtlinie 94/9/EG**

(3) EG-Baumusterprüfbescheinigungsnummer

ZELM 02 ATEX 0116X

(4) Gerät: **Messkopf Typ CST-Ex-...**

(5) Hersteller: **E-T-A Elektrische Apparate GmbH**

(6) Anschrift: **D-90518 Altdorf**

(7) Die Bauart dieses Gerätes sowie die verschiedenen zulässigen Ausführungen sind in der Anlage zu dieser Baumusterprüfbescheinigung festgelegt.

(8) Die Prüf- und Zertifizierungsstelle ZELM Ex bescheinigt als benannte Stelle Nr. 0820 nach Artikel 9 der Richtlinie des Rates der Europäischen Gemeinschaften vom 23. März 1994 (94/9/EG) die Erfüllung der grundlegenden Sicherheits- und Gesundheitsanforderungen für die Konzeption und den Bau von Geräten und Schutzsystemen zur bestimmungsgemäßen Verwendung in explosionsgefährdeten Bereichen gemäß Anhang II der Richtlinie.

Die Ergebnisse der Prüfung sind in dem vertraulichen Prüfbericht Nr. ZELM Ex 0270215156 festgelegt.

(9) Die grundlegenden Sicherheits- und Gesundheitsanforderungen werden erfüllt durch Übereinstimmung mit

EN 50 014: 1997+A1+A2 **EN 50 020: 1994** **EN 50284: 1999**
EN 50281-1-1:1998 **EN 1127-1: 1997**

(10) Falls das Zeichen "X" hinter der Bescheinigungsnummer steht, wird auf besondere Bedingungen für die sichere Anwendung des Gerätes in der Anlage zu dieser Bescheinigung hingewiesen.

(11) Diese EG-Baumusterprüfbescheinigung bezieht sich nur auf Konstruktion, Überprüfung und Tests des spezifizierten Gerätes oder Schutzsystems in Übereinstimmung mit Richtlinie 94/9/EG. Weitere Anforderungen der Richtlinie können für das Herstellungsverfahren und die Lieferung dieses Gerätes oder Schutzsystems gelten. Diese sind von vorliegender Bescheinigung nicht abgedeckt.

(12) Die Kennzeichnung des Gerätes muß die folgenden Angaben enthalten:

Ex **II 1/2 GD T130°C IP67 EEx ia IIC T4**

Zertifizierungsstelle **ZELM Ex**

Zertifizierungsstelle Prüf- und ZELM Ex

Braunschweig, 17.12.2002

Adolf Gruber

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Prüf- und Zertifizierungsstelle

ZELM Ex

(13) **Anlage**

(14) **EG-Baumusterprüfbescheinigung ZELM 02 ATEX 0116X**

(15) Beschreibung des Gerätes

Der Messkopf Typ CST-Ex-... dient zur Erfassung von Strömungsgeschwindigkeit und Mediumtemperatur von flüssigen, gasförmigen oder staubförmigen Medien.

Die maximal zulässige Umgebungstemperatur beträgt 75 °C.

Elektrische Daten

Versorgungs- und Signalstromkreis	in Zündschutzart Eigensicherheit EEx ia IIC nur zum Anschluss an einen bescheinigten eigensicheren Stromkreis mit folgenden
Höchstwerten:	U_o = 37,3 V I_o = 603 mA P_o = 1400 mW

Die maximale innere Kapazität und Induktivität sind vernachlässigbar klein.

(16) Prüfbericht Nr.

ZELM Ex 0270215156

(17) Besondere Bedingungen

1. Der eigensichere Stromkreis ist als nicht isoliert von dem metallischen Gehäuse zu betrachten. Es ist daher Potentialausgleich längs des gesamten Leitungszuges sicherzustellen.
2. Die Betriebsanleitung ist zu beachten, insbesondere hinsichtlich der Berücksichtigung geringerer Umgebungstemperaturen beim Einsatz gemäß Kategorie 1.
3. Der Explosionsschutz hängt insbesondere von der Dichtheit des Fühlermantels ab. Der Messkopf darf deshalb nur für solche Medien verwendet werden, für die der Fühlermantel hinreichend chemisch oder gegen Korrosion beständig ist.
4. Der Messkopf ist so zu Errichten, daß ein Lockern der Verschraubungen mit hinreichender Sicherheit ausgeschlossen werden kann.
5. Bei der Ausführung mit Titan als medienberührendes Teil ist insbesondere beim Einsatz gemäß Kategorie 1 die Möglichkeit des Auftretens von Schlag- und Reibfunken durch geeignete Montage auszuschließen.

(18) Grundlegende Sicherheits- und Gesundheitsanforderungen

durch Normen erfüllt

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ZELM Ex

(1) # EG-Baumusterprüfbescheinigung

(2) Geräte und Schutzsysteme zur bestimmungsgemäßen Verwendung in explosionsgefährdeten Bereichen – **Richtlinie 94/9/EG**

(3) EG-Baumusterprüfbescheinigungsnummer

ZELM 02 ATEX 0117

(4) Gerät: **Strömungsmesser Typ FM1-Ex**

(5) Hersteller: **E-T-A Elektrische Apparate GmbH**

(6) Anschrift: **D-90518 Altdorf**

(7) Die Bauart dieses Gerätes sowie die verschiedenen zulässigen Ausführungen sind in der Anlage zu dieser Baumusterprüfbescheinigung festgelegt.

(8) Die Prüf- und Zertifizierungsstelle ZELM Ex bescheinigt als benannte Stelle Nr. 0820 nach Artikel 9 der Richtlinie des Rates der Europäischen Gemeinschaften vom 23. März 1994 (94/9/EG) die Erfüllung der grundlegenden Sicherheits- und Gesundheitsanforderungen für die Konzeption und den Bau von Geräten und Schutzsystemen zur bestimmungsgemäßen Verwendung in explosionsgefährdeten Bereichen gemäß Anhang II der Richtlinie.

Die Ergebnisse der Prüfung sind in dem vertraulichen Prüfbericht Nr. ZELM Ex 0280215157 festgelegt.

(9) Die grundlegenden Sicherheits- und Gesundheitsanforderungen werden erfüllt durch Übereinstimmung mit

EN 50 014: 1997+A1+A2 **EN 50 020: 1994**

(10) Falls das Zeichen "X" hinter der Bescheinigungsnummer steht, wird auf besondere Bedingungen für die sichere Anwendung des Gerätes in der Anlage zu dieser Bescheinigung hingewiesen.

(11) Diese EG-Baumusterprüfbescheinigung bezieht sich nur auf Konstruktion, Überprüfung und Tests des spezifizierten Gerätes oder Schutzsystems in Übereinstimmung mit Richtlinie 94/9/EG. Weitere Anforderungen der Richtlinie können für das Herstellungsverfahren und die Lieferung dieses Gerätes oder Schutzsystems gelten. Diese sind von vorliegender Bescheinigung nicht abgedeckt.

(12) Die Kennzeichnung des Gerätes muß die folgenden Angaben enthalten:

Ex **II (1) GD [EEx ia] IIC**

Zertifizierungsstelle **ZELM Ex**

Adolf Gruber

Zertifizierungsstelle und Prüfstelle ZELM Ex

Braunschweig, 17.12.2002

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ZELM Ex

(13) **Anlage**

(14) **EG-Baumusterprüfbescheinigung ZELM 02 ATEX 0117**

(15) Beschreibung des Gerätes

Der Strömungsmesser Typ FM1-Ex dient zur Erfassung, Überwachung und Anzeige von Strömungsgeschwindigkeit, Durchflussmenge und Mediumtemperatur von flüssigen, gasförmigen oder staubförmigen Medien.

Der Strömungsmesser ist zur Installation außerhalb des explosionsgefährdeten Bereiches bestimmt. Er dient zum Anschluss von geeigneten Sensoren mit separater EG-Baumusterprüfbescheinigung.

Der zulässige Umgebungstemperaturbereich beträgt –10°C bis +43°C.

Elektrische Daten

Versorgungs- und Signalstromkreis	in Zündschutzart Eigensicherheit		EEx ia IIC
	Höchstwerte:	U_o = 37,3 V	
		I_o = 603 mA	
		P_o = 1400 mW	
	Die maximale zulässige äußere Kapazität beträgt		38 nF
	Die maximale zulässige äußere Induktivität beträgt		0,1 mH

Hinweise:

Die Betriebsanleitung ist zu beachten, insbesondere bezüglich der Einbeziehung in den Potentialausgleich des explosionsgefährdeten Bereiches.

(16) Prüfbericht Nr.

ZELM Ex 0280215157

(17) Besondere Bedingungen

nicht zutreffend

(18) Grundlegende Sicherheits- und Gesundheitsanforderungen

durch Normen erfüllt

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Table 1

Project:				Contact:		Date:
Sensor type:			C =	T =		
TRIM POINT	V_{ref} [m/s]	V_{fm1} [m/s]	Y_{T1} [digit]	Y_{T1} [Hz]	Y_{T2} [digit]	T1 = ... °C T2 = ... °C T = 50 + (Y_{T2} -Y_{T1})/(T2-T1)
20						
19						
18						
17						
16						
15						
14						
13						
12						
11						
10						
9						
8						
7						
6						
5						
4						
3						
2						
1						

Appendix 5 -Menu structure FC01-Ex (operator dialogue)